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Focus on: CD-ROM

AUDIO & HI-FI • COMPUTERS & MICROPROCESSORS • DESIGN IDEAS • RADIO, TELEVISION & COMMUNICATIONS • SCIENCE & TECHNOLOGY • TEST & MEASUREMENT

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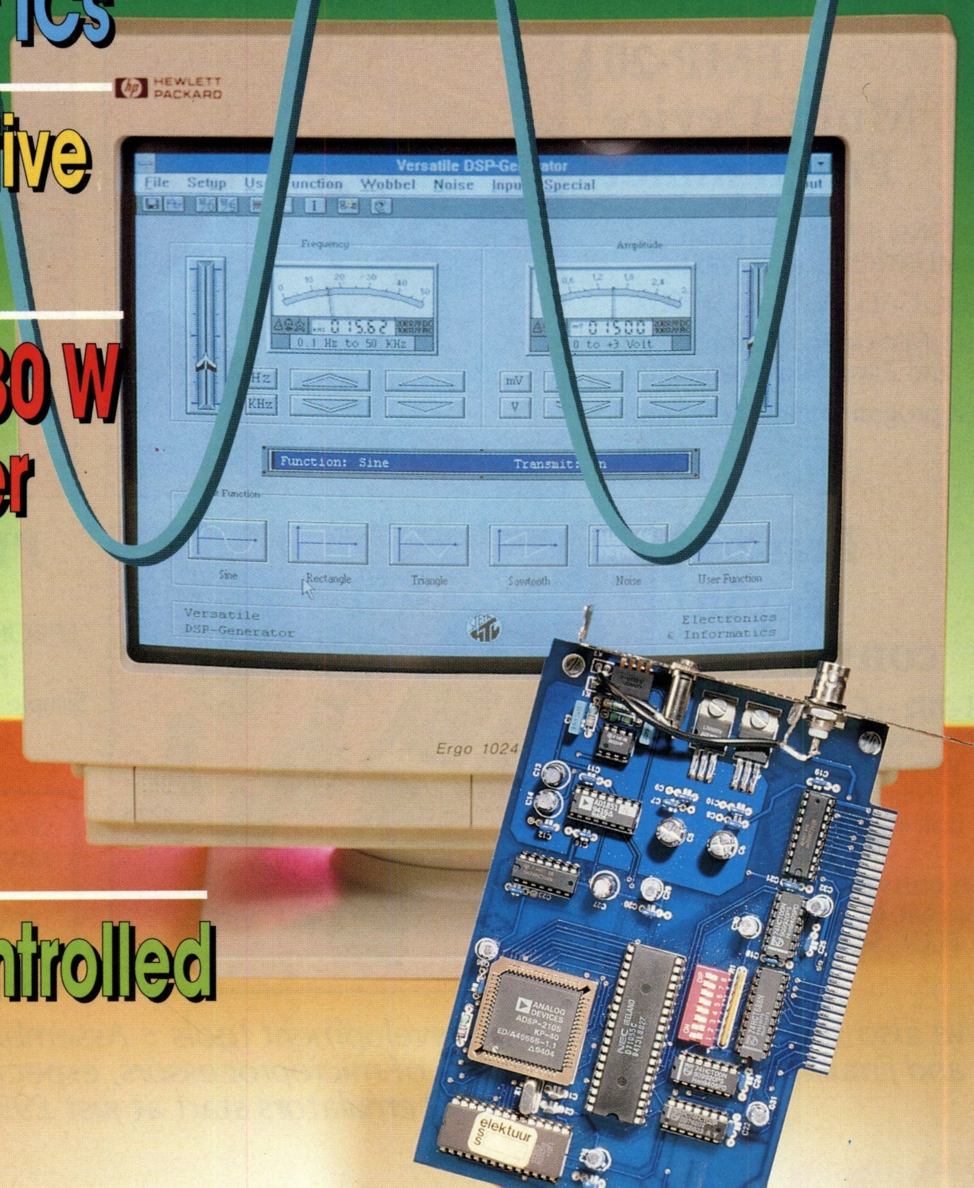
Stepper motor ICs

Wideband active loop antenna

TDA1560Q: a 30 W audio amplifier for cars

Long-life night light

Telephone-controlled mains switch



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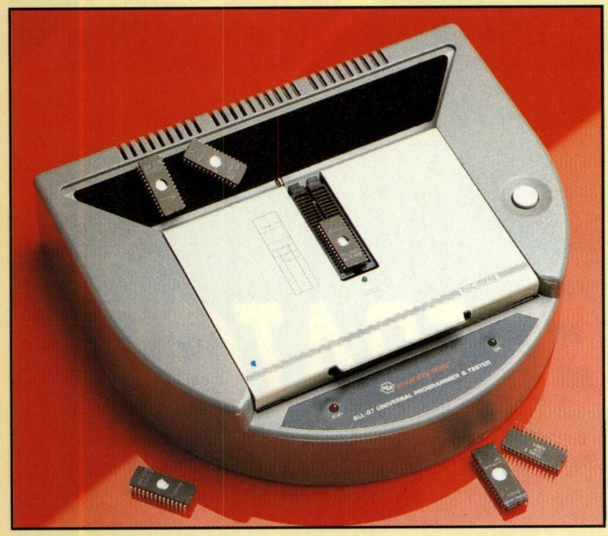

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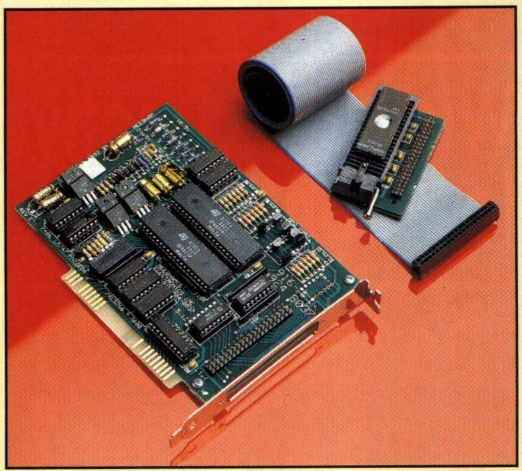

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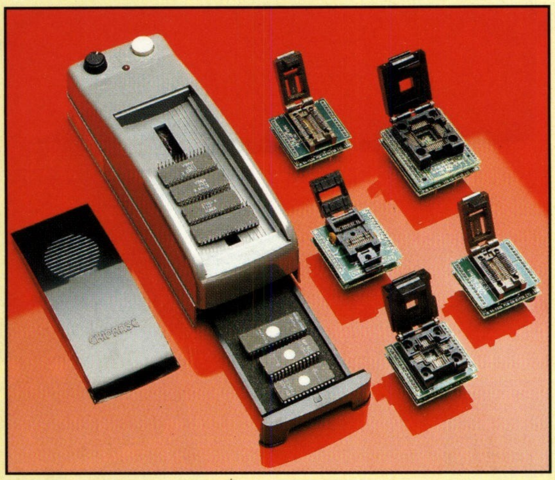

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- Stepper motor control
- Electronic barometer
- Simple function generator
- Bat detector
- and others for your continued interest.

Front cover

No electronics workshop or laboratory is complete without a function generator. The one described on p.42 is an insertion card for PCs and controlled entirely by software. The heart of the generator is a digital signal processor (see also p. 24) from Analog Devices. The card is controlled by a DOS or a Windows program supplied on disk (see p.70). The Windows version even allows you to create your own waveshapes.

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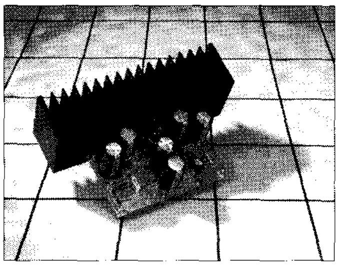

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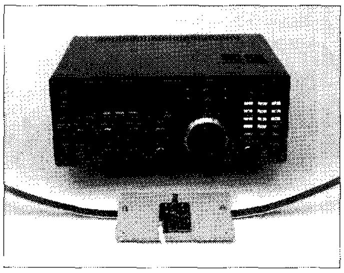

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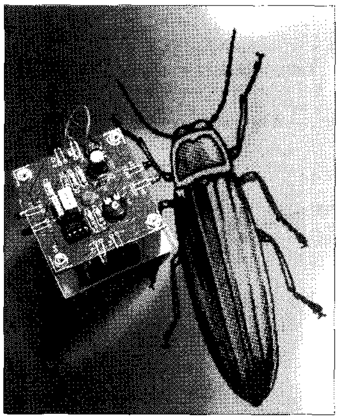

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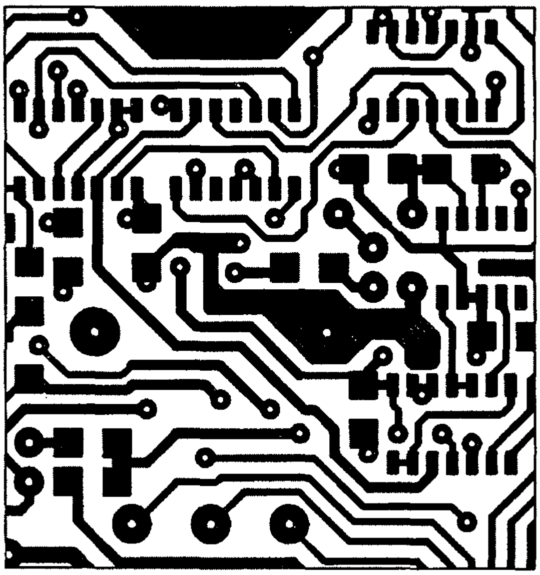

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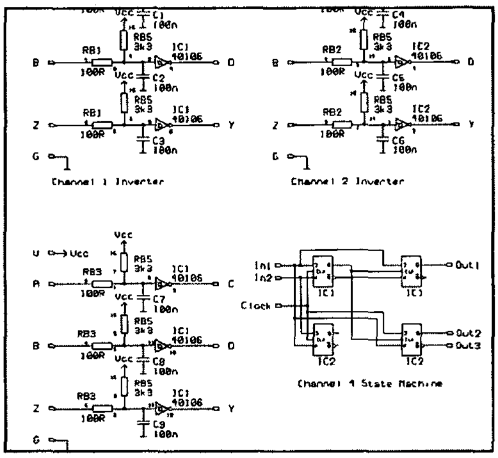

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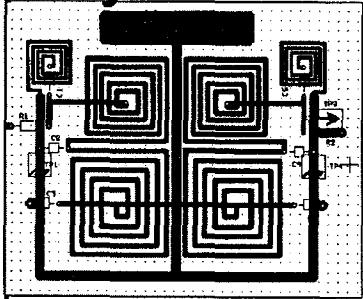

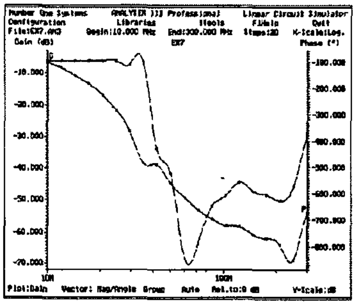

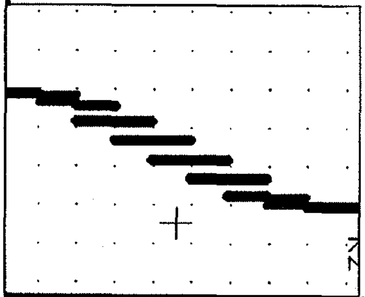

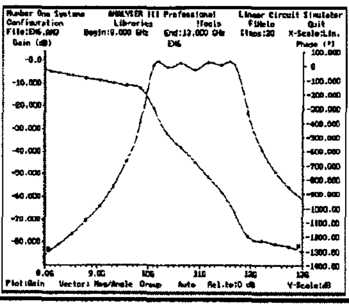

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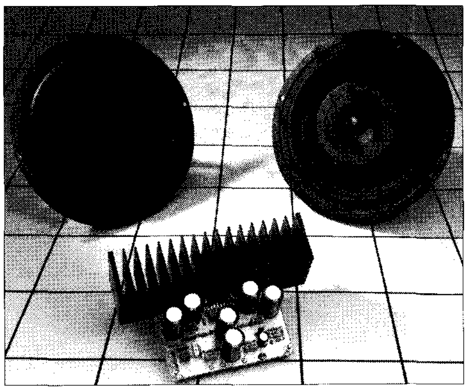
30 W AF AMPLIFIER FOR CARS



Design by T. Giesberts

The power that can be obtained from a standard car radio amplifier operating from a 12 V car battery is 5–6 W, which (for many listeners) is not really enough for satisfactory hi-fi reproduction. It is, of course, possible to boost the 12 V supply with a power inverter, but that is fairly expensive and not always acceptable. Now, a Philips IC enables audio power of about 30 W to be obtained from a 12 V car battery.

Until not so long ago, the Class B output stages of a standard car radio could not deliver more than 2× 5–6 W_{rms} into 4 Ω loudspeakers. More was not possible with a single supply line of 12 V. Most modern car radios use bridge amplifiers to boost the output to 12–16 W. Often, each of the four loudspeakers has its own dedicated amplifier. Many car manufacturers do not like the use of power inverters to raise the on-board voltage out of fear that these can cause (embarrassing or even dangerous) interference with the remainder of the electronic systems in the car (of which there can be many). There is also the problem of heat generation in the output stages, which may necessitate forced cooling.

Class H

Electronics manufacturers have been researching ways and means of obtaining adequate output power without the use of a power inverter, and Philips have come up with the TDA1560Q.

Output amplifiers can be arranged in a number of different configurations, of which most audio enthusiasts only know Class A and Class B. A different one that provides fairly high output power with relatively low dissipation is Class G. In this configuration, use is made of two supply voltages: a fairly low one that is constantly available and a much higher *one that becomes available only when* the the voltage swing of the output stages can not be sustained by the low supply voltage.

Since in cars only one supply voltage is available, Philips engineers have devised a pseudo Class G configuration in which a number of electrolytic capacitors are charged by the battery voltage. During brief voltage peaks in the output signal, semiconductor switches connect these capacitors in series with the 12 V line so that the supply voltage to the amplifier is temporarily doubled. Since this is a further development of the Class G technique, it is named Class H. The (temporary) 24 V supply to the amplifier enables (theoretically) a power of 80 W to be delivered into 4 Ω or 40 W into 8 Ω.

A simplified diagram of a Class H output amplifier is shown in **Fig. 1**. It contains two principal circuits: the first is a Class B amplifier, T_1–T_4, which is loaded by R_1, and the second raises the internal supply voltage. The second circuit uses two external capacitors, C_1 and C_2, which serve as supply buffers.

Since a music signal consists only

Brief Technical Data

Class H operation	
Low dissipation with music signals	
Extensive protection circuits (output current; temperature; load impedance)	
Supply voltage	12 V nominal
Quiescent current	100 mA
Output power	
(1 kHz sinusoidal, THD = 0.5%)	30 W r.m.s. into 8 Ω
(music signal)	40 W into 8 Ω
THD + noise (1 W into 8 Ω)	<<0.01% (1 kHz)
	<<0.05% (20 Hz to 20 kHz)
THD + noise (20 W into 8 Ω)	<<0.06% (1 kHz)
	<<0.2% (20 Hz to 20 kHz)
Power bandwidth (–3 dB)	5 Hz to 100 kHz

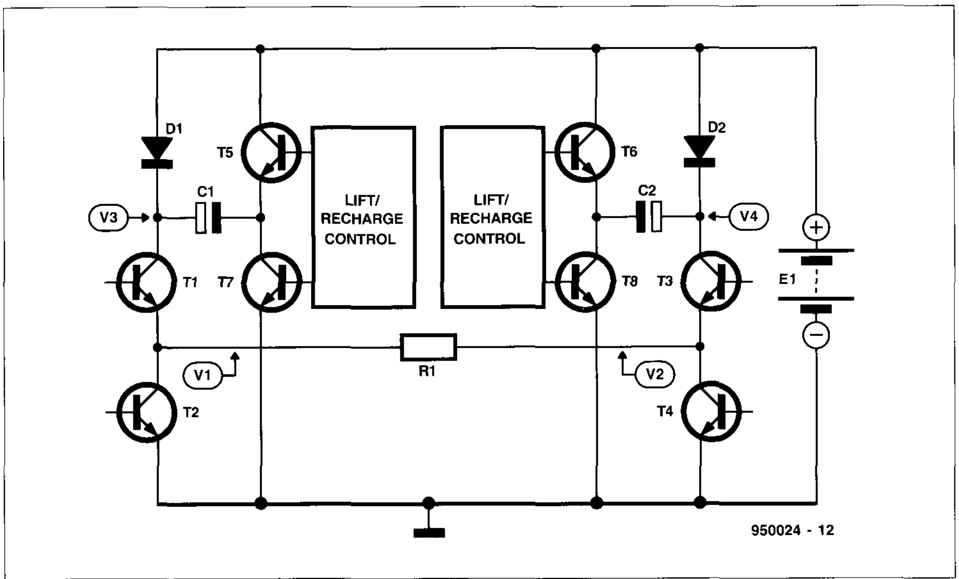


Fig. 1. Diagram of a basic Class H amplifier.

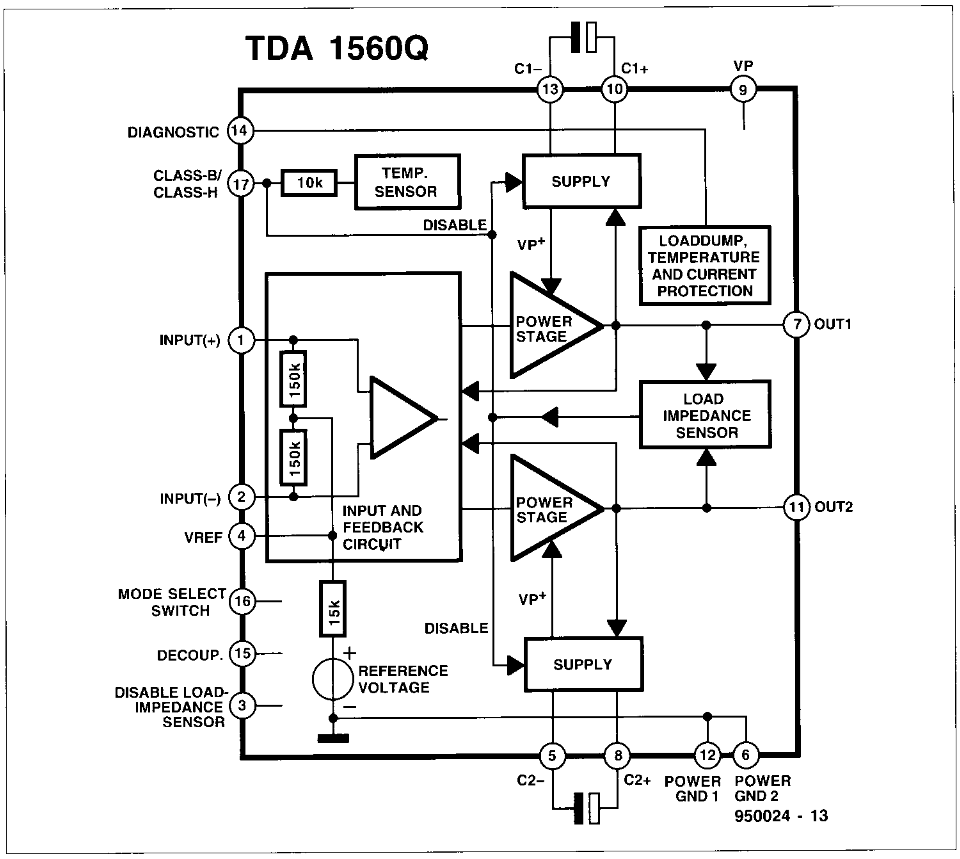


Fig. 2. Block diagram of the TDA1560Q

for a small part of high level components, the supply voltage needs to be raised for a small part of the time only.

Because the supply voltage is raised for short periods of time only, the average dissipated power will be only slightly higher than that of an amplifier without a voltage-raising circuit, in spite of the fact that the peak output power is appreciably higher.

Capacitors C_1 and C_2 are charged through current sources T_7 and T_8 to a voltage which is nearly equal to the supply voltage, E_1. When either voltage V_1 (or V_2) rises and T_1 (or T_3) approaches the saturation voltage, the lift control circuit detects this. Lift transistors T_5 and T_6 then conduct, so that the charged capacitors are switched between the collector of T_1 (or T_3) and supply voltage E_1. Diodes D_1 and D_2 prevent the capacitors being discharged via the battery. Voltage V_1 (or V_2) can increase to nearly twice the supply voltage. The lift/recharge control circuit ensures that T_5 and T_7, and T_6 and T_8, can not conduct simultaneously.

Inside the TDA1560Q

A block diagram of the TDA1560Q is shown in **Fig. 2**. A differential input stage in the input and feedback circuit is connected to pins 1 and 2. Because of this stage, the IC is highly insensitive to common-mode interference. The input impedance is 300 kΩ, so that for a good low-frequency response even small input capacitors are sufficient.

The input and feedback circuit contains circuitry that controls the supply circuits and the power stages.

The control circuitry monitors the input signal and anticipates saturation of the output transistors. As soon as this happens, the supply voltage is raised. Because the input signal is monitored, it is possible to control the lift voltage. To keep the dissipation at a minimum, the supply voltage is raised only to a level where the output will stay below the clipping level.

A current limiter protects the out-

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put stages against being short-circuited to ground or to the supply line. In general, whenever the current drawn exceeds a level of 5.5 A, the output and the power stages are switched off. The protection circuit monitors at short intervals whether the short-circuit has been removed. If so, the output stages are reactuated. This arrangement limits the dissipation in the power stages during short-circuits to a minimum.

There is a dual temperature protection. The first switches off the voltage doublers when the temperature of their cases rises above 120 °C. The amplifier can then operate in Class B only. The second protection uses sensors located close to the output and switching transistors. If these sensors measure a temperature higher than 165 °C, the base current of the associated transistor is lowered.

There is also a circuit that monitors the load impedance. After the amplifier has been switched on, the d.c. resistance of the loudspeaker(s) is determined by passing a current through the speaker coil(s) and measuring the consequent voltage drop across it.. Because of the peak current that the power stages can handle, the Class H section is switched off when a 4 Ω loudspeaker is detected. The IC then operates as a Class B amplifier. When the load impedance drops below 0.5 Ω, it is considered a short circuit and the entire IC is disabled. The impedance sensor is very sensitive and may be actuated by spurious pulses (for instance, when a car door gets closed during switch-on: the loudspeakers then act as microphones). The sensor may be disabled by shorting pin 3 to ground.

Finally, the IC contains an internal reference voltage source for the input circuits. This reference is decoupled by a capacitor at pin 4.

Circuit description

The circuit diagram of the 30 W AF amplifier is shown in **Fig. 3**. The input is connected to the differential input stage (pins 1 and 2) via coupling coupling capacitors C_1 and C_2. Although the –ve input is linked to earth via wire bridge A-B, the arrangement gives good common-mode rejection in spite of the assymetrical input. A true symmetrical input is obtained when wire bridge A-B is omitted from the board. Network R_1-C_3 forms a low-pass filter that suppresses HF interference at the input. The input impedance is determined largely by the value of R_2.

The circuit around darlington T_1 provides a delay at switch-on to suppress switching noise reaching the output stages. This is essential since the impedance measuring sensor (which normally provides the suppression) has been disabled here (pin 3 to ground).

As soon as the supply voltage is on, a potential of 3 V is applied to pin 16 via R_3 and D_1 to place the IC in the mute mode. Initially, since C_{10} is discharged, T_1 remains off. However, the capacitor then gets charged via R_4 and within a few seconds the voltage across it has risen to a level at which T_1 begins to conduct. This results in a voltage of 12 V being applied to pin 16, whereupon the power stages operate normally.

Various facilities are open to the user via pin 14. For instance, it may be used to detect whether one of the protection circuits is working. Normally, this pin is at the level of the supply voltage. If its potential is only half that value, one of the protection circuits is actuated. When the pin is linked to ground via jumper JP_1, the amplifier is muted. When the jumper is connected to +12 V, all protection circuits are disabled. For normal operation, therefore, no jumper should be placed at JP_1.

Capacitors C_{15} and C_{16} buffer the 12 V battery voltage. Capacitors C_{11}-C_{12} and C_{13}-C_{14} are required by the lift/control circuit. Two parallel-connected 4700 µF electrolytic capacitors are used in each case, because these take up less space on the board than a single 10,000 µF component. Networks R_6-C_6 and R_7-C_7 are interference suppressors.

A Boucherot network, R_8-C_8 and R_9-C_9, is provided at each loudspeaker terminal to maintain a 'normal' load at high frequencies (at which the loudpeaker impedance rises appreciably owing to its inductive behaviour).

Construction

The construction is limited to populating the printed-circuit board shown in **Fig. 4**. The IC must protrude slightly from the board so that it can be fitted flush against the heat sink. An insulating washer between IC and heat sink is a must: apply heat conducting paste to both the base of the IC and the heat sink. The insulating washer may have to be cut to size from a mica T03 washer.

Most constructors will use two amplifiers in one enclosure for a compact stereo setup. It is, however, also possible to use four amplifiers in one case: one for each

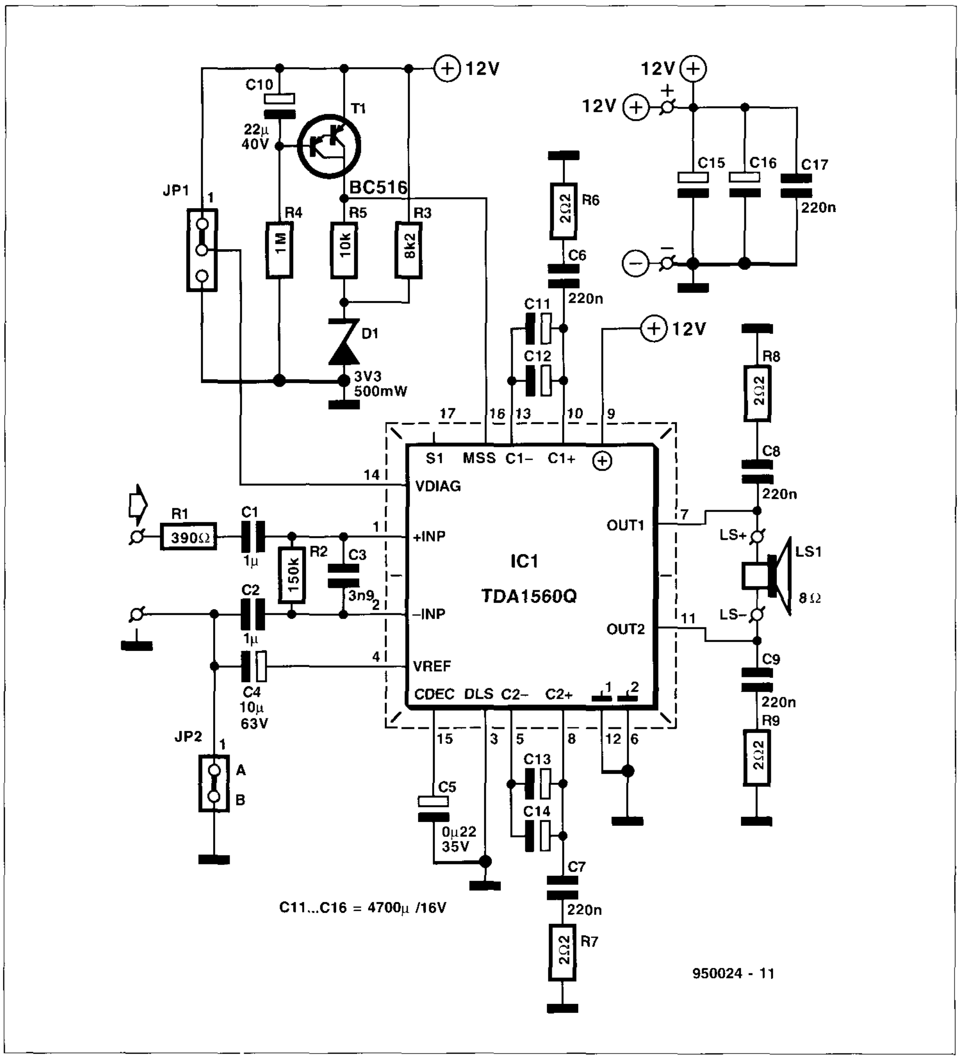

Fig. 3. Circuit diagram of the 30 W AF amplifier for cars.

of the two front and rear speakers. Make sure that none of the loudspeaker cables or terminals can touch the chassis, because that does not do the bridge amplifier any good in the long term in spite of the protection circuits.

Parts list

Resistors:
R_1 = 390 Ω
R_2 = 150 kΩ
R_3 = 8.2 kΩ
R_4 = 1 MΩ
R_5 = 10 kΩ
R_6–R_9 = 2.2 Ω

Capacitors:
C_1, C_2 = 1 μF, pitch 5 mm
C_3 = 3.9 nF
C_4 = 10 μF, 63 V, radial
C_5 = 220 nF, 35 V, tantalum
C_6–C_9, C_{17} = 220 nF
C_{10} = 22 μF, 40 V, radial
C_{11}–C_{16} = 4700 μF, 16 V, radial

Semiconductors:
D_1 = zener, 3.3 V, 500 mW
T_1 = BC516

Integrated circuits:
IC_1 = TDA1560Q

Miscellaneous:
Heat sink for IC_1; R_{th} <<2.5 K W^{-1}
PCB Order No. 950024-1

[950024]

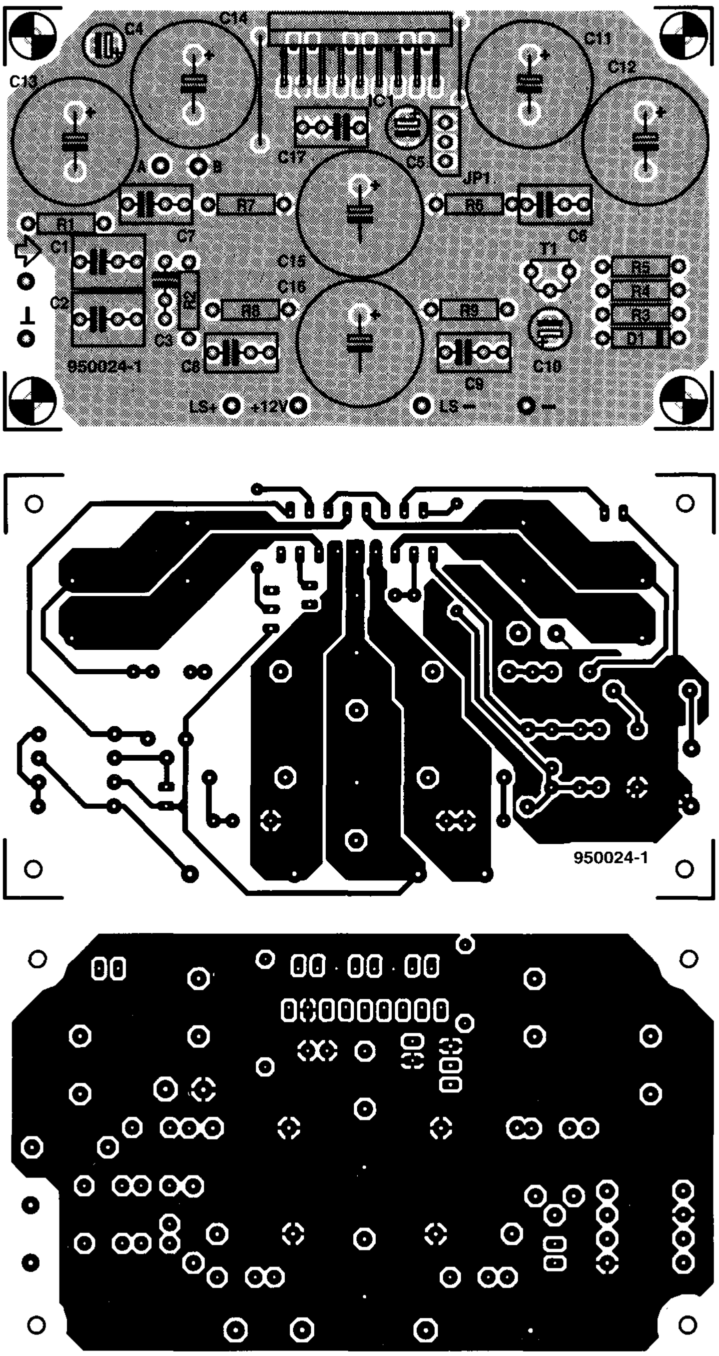

Fig. 4. Printed circuit board for the 30 W AF amplifier for cars.

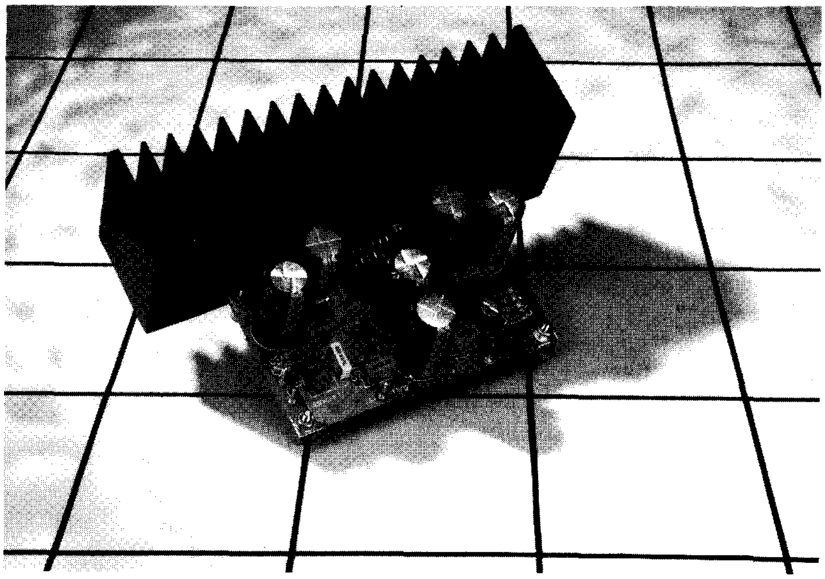

Fig.5. The completed (prototype) 30 W AF amplifier for cars.

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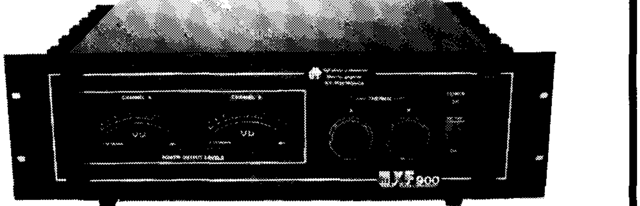

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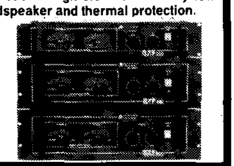

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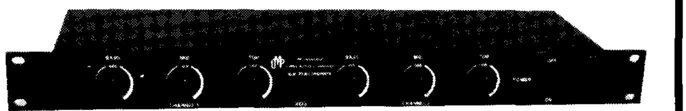

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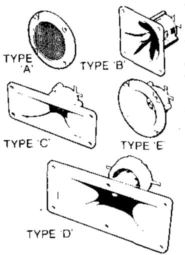

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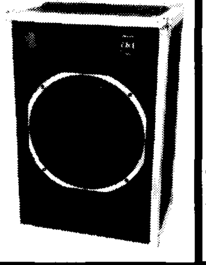

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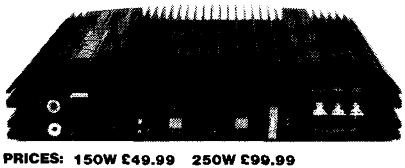

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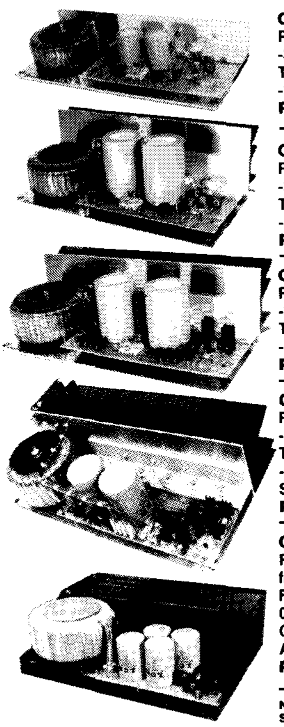

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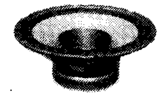

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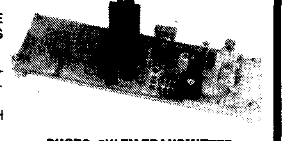

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WIDEBAND ACTIVE LOOP ANTENNA

Wideband antenna design is problematic because size and performance are conflicting aspects. The wideband antenna described in this article covers the long, medium and shortwave bands up to about 50 MHz, and achieves excellent efficiency while remaining reasonably sized.

Design by J. Barendrecht

MANY shortwave DXers lack the space to erect a large, tuned, antenna, and have to resort to much smaller alternatives. Not surprisingly, these are nearly always active antennas, which are expected to do 'the impossible' (well, almost). Ideally, they should have a low noise level, good large signal handling, wideband characteristics with a stable output level across the entire frequency range, and, last but not least, they should be usable in areas with a high noise level (i.e., in and around the city). Unfortunately, you can not expect all that from an active antenna. Low noise and a wideband response, for instance, are contending aspects, while immunity against man-made noise is very difficult to achieve. However, if the latter aspect is the most important (and in many cases it will, unless you live in the middle of nowhere), there is no alternative than to use a rhombic or loop antenna, which (ideally) responds to the magnetic component only of the energy picked up from the transmitter. Because it ignores electric components, this type of antenna keeps out a lot of man-made interference.

However, choosing a loop antenna does not solve all problems because good wideband response is difficult to achieve with this type of antenna. The voltage induced in the antenna drops significantly below the resonance frequency. At higher frequencies, too, problems occur because the induced voltage is in series with the loop's self-inductance. This, in combination with the amplifier's input capacitance, creates a low-pass filter with a roll-off frequency which can be so low that it becomes a troublesome factor. Consequently, it is essential to ensure proper matching between the passive part of the antenna (i.e., the loop) and the active part (i.e., the amplifier). In all cases, however, the best you will be able to achieve is still a trade-off.

A MOSFET amplifier

Recapping the above, the active part of the antenna should couple good large signal behaviour with low noise, and in addition present a very low input capacitance.

The circuit diagram shown in **Fig. 1** shows the amplifier sitting between the loop (which will be reverted to) and the phantom power supply. A dual-gate MOSFET, T_1, is used as a transconductance amplifier to match the impedance of the loop to that of the output coax cable. Transistor T_2 is the actual amplifying device. Some of you may wonder about the use of the BF981 MOSFET, which would appear to be designed for VHF/UHF applications only. However, the specifications of this MOSFET indicate that it also has low noise at lower frequencies, provided its very high input impedance is properly matched.

Input matching is not a problem at relatively low frequencies. The loop antenna used here has a diameter of about 1 m (3 feet), and its low impedance at low frequencies is easily stepped up. Problems occur at higher frequencies, however, because then the self-inductance of the loop (approx. 5 μH) is also stepped up, and starts to cause trouble. The BF981 has an input capacitance of about 2 pF, while the capacitance of a regular input transformer lies between 0.5 pF and 1 pF. Some form of damping is, therefore, required to prevent unwanted resonance peaks. Although that can be achieved by the simple addition of a resistor, everything possible has to be done not to attenuate the already weak signals picked up by the antenna. Hence, some means of damping the loop has to be devised which does not unduly attenuate the RF signal.

The problem is not new, of course, and had to be contended with in the design of RF stages in early FM receivers using valves. Triodes offered a lower noise figure than pentodes, but only if neutralizing (or 'neutrodyne') techniques were applied. If that could not be done, there was the grounded grid amplifier to resort to. Not a good alternative, though, because it had a higher noise figure, and offered less gain.

A compromise was found in the

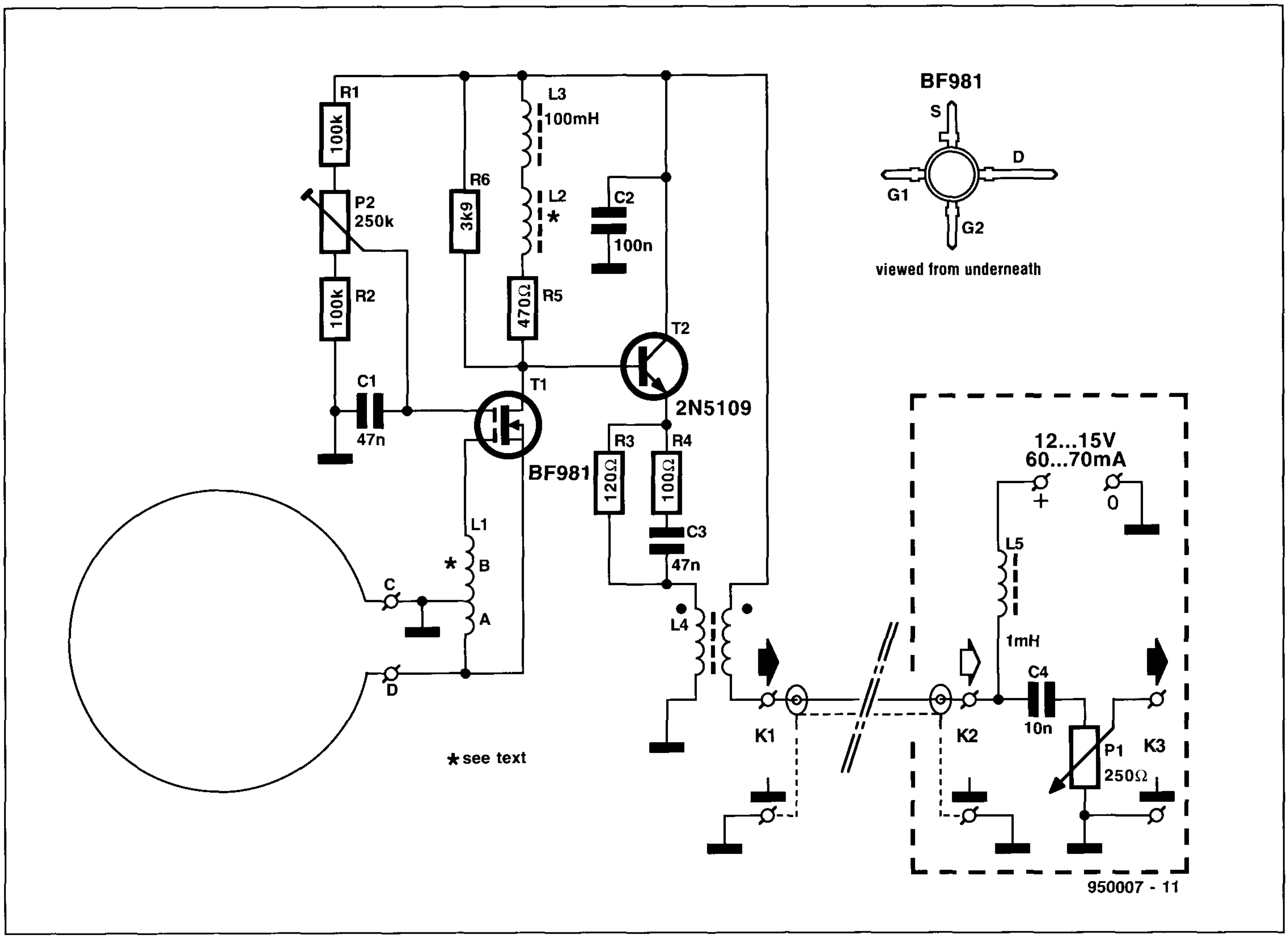

Fig. 1. The heart of the active antenna is formed by dual-gate MOSFET T1, a BF981. The antenna proper consists of a loop with a diameter of about 1 m.

inter-grid or inter-base amplifier. This type of bridge circuit required no neutralizing, and did not degrade the noise figure with respect to the common-cathode amplifier.

The amplifier used here revives the above technology, and may be called an inter-gate type (the electrical behaviour of a MOSFET being very similar to that of a thermionic valve). This circuit is easy to recognize from the fact that the source of the MOSFET is connected to the input transformer rather than to ground, while the tap on the transformer is connected to ground. The amplifier is therefore, best classified between a grounded-gate and a grounded-source circuit.

Here, the choice of an inter-base circuit has nothing to do with avoiding neutralization as in the valve era — the prime design targets are now (1) matching and (2) damping. As already mentioned, there are no problems at relatively low frequencies. The output impedance of T_1 (approx. 100 Ω) is then insignificant, and the gate-source voltage is about six times the voltage induced in the loop. From about 3.4 MHz, the source input starts to act as a damping resistance, which eliminates resonance effects while extending the bandwidth of L_1. Precisely what we are after!

As a matter of course, the damping reduces the signal level supplied by the loop. The loop output voltage being small already, the MOSFET has to provide considerable gain at higher frequencies also. This has been achieved by inserting an inductor-resistor combination, R_5-L_2, between the drain of T_1 and choke L_3. The *RL* combination ensures a high drain impedance at higher frequencies also, because L_3 then has a fairly high capacitive reactance. Resistor R_6 keeps the gain of T_1 within reasonable limits.

The amplified signal is coupled out via emitter follower T_2 and a bifilar output transformer, L_4. From there, the signal is fed to the input of the receiver. At the receiver side, a small passive network is fitted. A potentiometer, P_1, is available to reduce the input signal when necessary. This control will be particularly useful when the active antenna is used with a receiver suffering from poor or average large-signal handling.

Choke L_5 and capacitor C_4 allow the RF signal and the preamplifier's supply voltage to be carried via the same coax cable. In most cases, it will be possible to take the supply voltage from the receiver. If not, the simplest of regulated power supplies is also fine, the current consumption of the preamplifier being modest at between 60 mA and 70 mA.

The loop antenna

The antenna proper consists of a loop with a diameter of about 1 m. Ideally, the loop should be made from metal tubing with a diameter of about 20 mm. The choice of metal is not so important. Plate material or even rectangular tubing of the same width may be used also. Ordinary copper wire is not suitable because it is too thin.

Those of you who live outside Europe may make the loop much larger to increase the output voltage and the signal-to-noise ratio. In Europe, a diameter of about 1 m is just

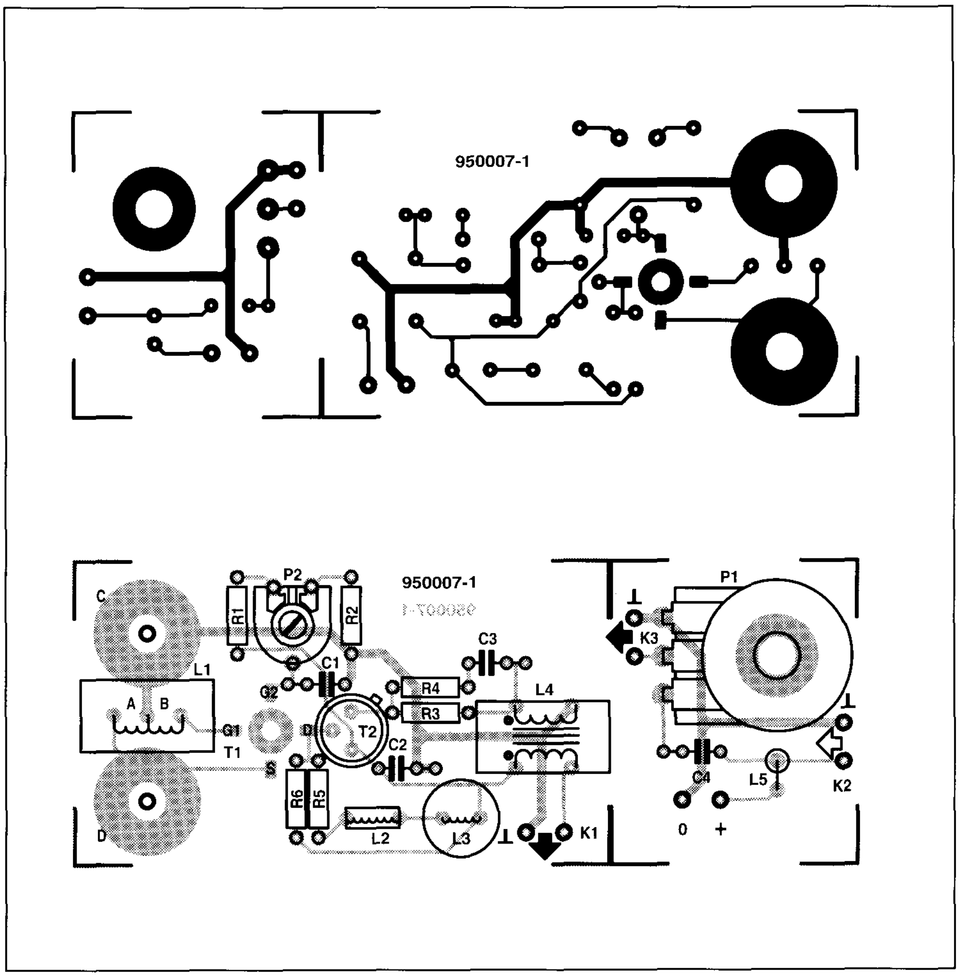

Fig. 2. The printed circuit board consists of two sections, which should be separated before they are populated. The section which has the potentiometer (P1) on it corresponds to the sub-circuit in the dashed box in Fig. 1.

COMPONENTS LIST

Resistors:
R_1,R_2 = 100kΩ
R_3 = 120Ω
R_4 = 100Ω
R_5 = 470Ω
R_6 = 3kΩ9
P_1 = 250Ω
P_2 = 250kΩ preset H

Capacitors:
C_1,C_3 = 47nF Sibatit (Siemens)
C_2 = 100nF Sibatit (Siemens)
C_4 = 10nF Sibatit (Siemens)

Inductors:
L_1 = 24 turns 0.4 mm CuL (A = 4 turns, B = 20 turns), on ferrite ring core G2.3-FT16 *.
L_2 = 20 turns 0.4 mm CuL, no core, diameter 6 mm.
L_3 = 100mH (Toko 10RB-181LY-104).
L_4 = 4+4 turns 0.3 mm CuL, bifilar on ferrite ring core G2.3-FT16 *.
L_5 = 1 mH (Toko).

Semiconductors:
T_1 = BF981
T_2 = 2N5109 (SGS Thomson)

Miscellaneous:
K_1;K_2,K_3 = BNC-socket.
PCB not available ready-made through the Readers Services.

* C-I Electronics, P.O. Box 22089, NL-6360-AB Nuth, The Netherlands. Fax: (+31) 45 241877.

about the maximum because of the very high signal levels which exist as a result of the area being the target of a very large number of short-wave broadcast transmitters. Increasing the loop diameter will, therefore, almost certainly cause input blocking effects in the receiver. A smaller loop is, of course, possible, although that will reduce the performance.

Construction

The artwork of the printed circuit board designed for the active antenna is shown in **Fig. 2**. Unfortunately, this board is not available ready-made through our Readers Services, so you will have to make it yourself. Two important points have to be mentioned with respect to this board. The first is that the right-hand section has to be cut off because it holds the sub-circuit which is fitted inside or near the receiver. Secondly, the loop ends must be connected directly to points 'C' and 'D' on the board. In practice, it is best to secure the board between the loop ends.

Populating the board is straightforward with the possible exceptions of mounting T_1 and making the inductors. The MOSFET, T_1, is fitted at the **copper** side of the board. Its type number should be legible when looking through the hole in the board from the component side. The longest terminal of the device is the drain (see also the pinout inset in Fig. 1).

The circuit has a total of five inductors. Three of these, L_1, L_2 and L_4, are home-made, while L_3 and L_5 are off-the-shelf chokes. L_2 consists of 20-turns of 0.4-mm dia. enamelled copper wire, and has an internal diameter of 6 mm. No core is used, and the inductor may be wound on, say, a PCB spacer. L_1 and L_4 are both wound on a ferrite ring core type G2.3-FT16. L_1 consists of 24 turns with a tap at 4 turns; L_{1A} has 4 turns, and L_{1B}, 20 turns. Use 0.4 mm dia. (28SWG) enamelled copper wire. L_4 is wound with slightly thinner wire (0.3 mm dia, 30SWG), and has two bifilar windings of 4 turns each. Bifilar means that you wind two wires at a time, so that the inductor halves run alongside each other. In all home-made inductors, the wire is close-wound, i.e., it is not spaced.

The prototype of the preamplifier board is shown in **Fig. 3**. The photograph gives a fair indication of the construction of the home-made inductors.

Finally, a word about fitting the circuit into a case. The case should be a plastic type. If the antenna is installed out of doors, a watertight case should be used. Connectors K_1, K_2 and K_3 should be good-quality BNC types.

Adjustment

You do not need expensive test equipment to adjust the active antenna. A multimeter, a short-wave receiver and a good sense of hearing are all that is needed.

To begin with, adjust preset P_2 until the voltage at the drain of T_1 is 1 V higher than half the supply voltage, i.e., 7 V if the supply voltage is 12 V, or 8.5 V if the supply voltage is 15 V. Next, check during the evening hours that signals in the 41-m, 31-m and 25-m broadcast bands are sufficiently

BASIC Stamp -Stamp sized Computer runs BASIC

The Basic Stamp by PARALLAX measures only 40x60mm yet is a true microcomputer that runs BASIC programmes written on your PC. Its size, ease of use and extensive I/O features make it an ideal tool for both educational and industrial applications as well as for the serious hobbyist.

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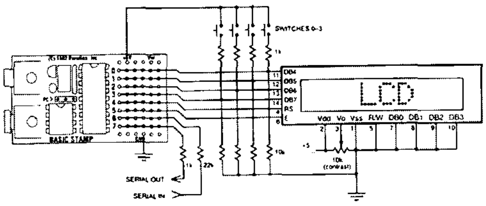

Typical Application

The BASIC Stamp Development Kit at £99 includes; 1 BASIC Stamp, instruction manual, PC cable, software and extensive application notes. Further Stamps are available from £29.

PIC Development Tools -from £89

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PIC 16C71/84 TrueFlight	●	●		●	●				●	●		16	
BackDraft 17	●			●							●		PLCC
ClearView '5x			●	●	●		●					20	
ClearView 'xx			●	●	●			●	●	●		20	
B.LO.C Compiler				●		●	●	●	●	●	●		
PIC Experiment Board							●		●	●			
PIC Prototyping Boards							●	●	●	●	●		
Parallax Assembler				●			●	●	●	●			
Parallax Simulator					●		●		●	●			

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strong. A considerable improvement should be noted over the regular whip antenna. If not, run a thorough check on the complete circuit.

If the antenna appears to work so far, the receiver is tuned between 21 MHz and 21.5 MHz (13-m band). Listen carefully for spurious signals in this band like harmonics, 'birdies', 'whistles' or intermodulation products. If such signals are noted, the receiver is probably overdriven. If the spurious signals do not disappear when the input level is reduced by operating potentiometer P_1, carefully adjust the preset, P_2, until a setting is found at which the level of the spurious signals is at a minimum. Next, tune to a weak signal in the 13-m band to check that the new setting does not unduly decrease the signal-to-noise ratio. possibly, a minor adjustment of P1 brings some improvement.

Finally, the above mentioned time for the adjustment is only valid for the winter months, and in the spring up to the end of April. In the summer months, the adjustment is best done around midnight.

(950007)

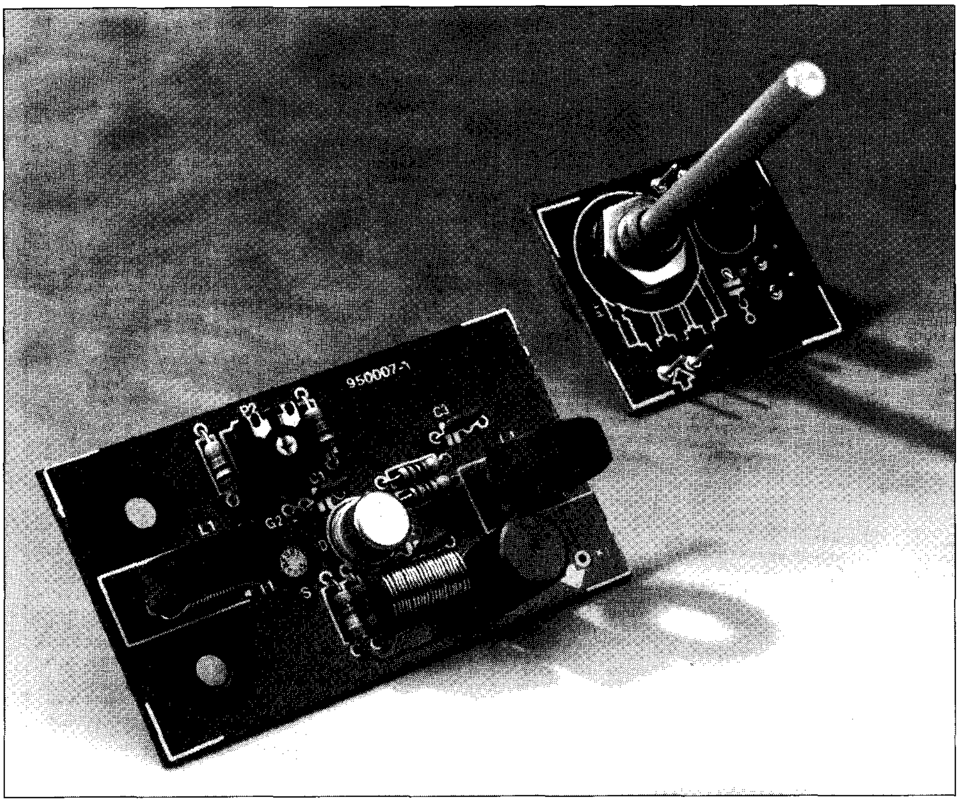

Fig. 3. Although three inductors in the circuit are home made, the circuit is simple to build.

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4011UB	0.28
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4023UB	0.23
4024AE	0.30
4024B	0.32
4025B	0.24
4025UB	0.30
4026B	0.94
4027B	0.30
4028B	0.38
4029B	0.39
4030B	0.34
4031B	1.24
4032B	0.70
4033B	0.68
4034B	2.10
4035B	0.52
4036B	2.98
4037B	1.27
4038B	0.78
4039B	3.22
4040B	0.42
4041B	0.48
4041UB	0.48
4042B	0.38
4043B	0.39
4044B	0.39
4045B	1.10
4046B	0.44
4047B	0.44
4048B	0.82
4049B	0.30
4049UB	0.28
4050B	0.28
4051B	0.34
4052B	0.33
4053B	0.36
4054B	0.79
4055B	0.62
4056B	0.82
4059B	3.15
4060B	0.38
4063B	0.58
4066B	0.27
4067B	2.28
4068B	0.28
4069UB	0.22
4070B	0.22
4071B	0.22
4072B	0.22
4073B	0.28
4075B	0.22
4076B	0.64
4077B	0.28
4078B	0.28
4081B	0.22
4082B	0.22
4085B	0.56
4086B	0.56
4089B	0.98
4093B	0.26
4094B	0.38
4095B	0.70
4096B	1.10
4097B	2.75
4098B	0.84
4099B	0.42
4104P	1.01
4106B	0.88
4160B	1.40
4161B	1.20
4163B	1.20
4174B	1.20
4175B	1.14
4194B	1.43
4409P	11.05
4410P	16.45
4411P	21.58
4412FP	POA
4412VP	POA
4416P	POA
4419P	POA
4429PB	POA
4433P	POA
4443P	POA
4447P	POA
4467P1	7.20
4468P	6.94
4469P	POA
4489P	POA
4490P	4.80
4495P	6.98
4497P	6.98
4499P	6.98
4500B	15.80
4501UB	0.44
4502B	0.56
4503B	0.48
4504B	1.36
4505B	POA
4506B	1.40
4506UB	1.40
4508B	1.68
4510B	0.54
4511B	0.44
4512B	0.66
4513B	6.60
4514B	1.12
4515B	1.12
4516B	0.44
4517B	1.84
4518B	0.44
4519B	0.36
4520B	0.44
4521B	0.84
4522B	0.86
4526B	0.60
4527B	0.58
4528B	0.49
4529B	0.74
4530B	2.24
4531B	1.18
4532B	0.88
4534B	2.82
4536B	1.88
4538B	0.60
4539B	0.62
4541B	0.56
4543B	0.57
4544B	3.58
4547B	3.25
4549B	7.60
4551B	1.62
4553B	2.95
4554B	POA
4555B	0.82
4556B	0.82
4557B	1.98
4558B	2.64
4560B	1.62
4561B	1.96
4562B	5.82
4566B	1.10
4568B	5.82
4569B	3.04
4572UB	0.84
4573P	6.98
4580B	8.84
4581B	POA
4582B	POA
4583B	1.38
4584B	0.89
4585B	0.74
4597B	6.60
4598B	7.40
4599B	5.82
4720B	POA
4720V	POA
4723B	POA
4724B	0.98
4731VP	9.80
4737VP	19.60
4738VP	19.74
4750VD	28.50
4752VP	29.25
4753VP	POA
4754VP	POA
40085	POA
40097	0.68
40098	0.68
40100	POA
40101	POA
40102	1.86
40103	1.14
40105	POA
40106	0.32
40107	0.42
40108	POA
40109	1.24
40110	1.62
40114	3.40
40116	POA
40117	POA
40147	1.23
40160	0.92
40161	0.54
40162	0.72
40163	0.72
40174	0.42
40175	0.42
40181	POA
40192	0.62
40193	0.74
40194	POA
40195	POA
40240	POA
40244	1.36
40245	1.36
40257	0.98
40373	1.34
40374	1.34
45026	POA
45027	5.99
45028	POA
45040	POA
45041	POA
45100	1.56
45106	POA
45109	POA
45145	13.96
45146	13.96
45151P2	18.46
45152P2	18.46
45155P2	13.96
45156P2	13.96
45157P2	11.08
45158P2	11.08
45159	POA
45403P	POA
45406P	3.56
45407P	6.47
45411P	POA
45414P	POA

4000 SERIES SURFACE MOUNT

4001BT	0.32
4002BT	0.32
4011BT	0.32
4011UBT	0.32
4012BT	0.32
4013BT	0.45
4015BT	0.84
4016BT	0.43
4017BT	0.78
4018BT	0.78
4020BT	0.95
4021BT	0.65
4023BT	0.38
4024BT	0.76
4025BT	0.38
4027BT	0.45
4028BT	0.56
4029BT	0.86
4040BT	0.78
4042BT	0.74
4046BT	1.41
4047BT	1.06
4049BT	1.06
4050BT	0.48
4051BT	0.78
4052BT	0.84
4053BT	0.98
4060BT	0.84
4066BT	0.59
4068BT	0.38
4069UBT	0.38
4070BT	0.38
4071BT	0.38
4075BT	0.38
4077BT	0.38
4078BT	0.38
4081BT	0.38
4093BT	0.45
4094BT	0.95
4508BT	2.05
4510BT	1.02
4511BT	1.35
4512BT	0.68
4514BT	2.20
4516BT	1.02
4518BT	1.18
4520BT	1.18
4521BT	1.07
4522BT	1.22
4528BT	0.88
4534BD	POA
4538BT	1.05
4541BT	1.05
4543BT	1.02
4555BT	POA
4556BT	1.05
4585BT	0.95
40106BT	0.53
40244BT	1.35
40373BT	2.34

74 SERIES

7400	0.36
7401	0.30
7402	0.32
7403	0.32
7404	0.34
7405	0.34
7406	0.68
7407	0.61
7408	0.37
7409	0.38
7410	0.35
7412	0.64
7413	0.76
7414	0.64
7416	0.48
7417	0.48
7420	0.37
7425	1.10
7426	0.48
7427	0.59
7430	0.35
7432	0.45
7437	0.54
7438	0.46
7440	0.77
7442	0.54
7445	1.12
7446	1.38
7447	0.98
7447A	1.40
7451	0.57
7454	0.72
7470	0.54
7472	0.38
7473	0.56
7474	0.53
7475	0.64
7476	0.64
7480	1.26
7483	1.10
7485	0.58
7486	0.53
7490	0.72
7490A	0.72
7491	2.56
7492	0.67
7493	0.60
7493A	0.60
7497	4.48
74104	0.67
74107	0.60
74110	POA
74116	3.10
74118	POA
74119	POA
74121	1.40
74123	0.88
74125	0.64
74126	0.98
74128	1.42
74132	0.86
74145	1.10
74150	1.86
74151	0.80
74153	0.90
74154	2.80
74155	0.81
74157	0.74
74158	1.57
74159	3.89
74160	0.94
74161A	0.74
74163	1.28
74164	1.16
74165	1.57
74166	1.06
74174	1.37
74175	1.10
74180	1.16
74184	POA
74185	1.76
74191	1.26
74192	1.41
74193	1.65
74221	2.40
74259	2.92
74265	1.46
74273	POA
74276	5.18
74279	POA
74283	POA
74298	POA
74365	POA
74367	POA
74393	4.89
74403	POA
74423	POA

74LS SERIES

74LS00	0.18
74LS01	0.24
74LS02	0.18
74LS03	0.20
74LS04	0.21
74LS05	0.21
74LS06	0.51
74LS07	0.51
74LS08	0.18
74LS09	0.20
74LS10	0.18
74LS11	0.18
74LS12	0.18
74LS13	0.24
74LS14	0.24
74LS15	0.38
74LS20	0.20
74LS21	0.20
74LS22	0.24
74LS24	0.68
74LS26	0.20
74LS27	0.20
74LS28	0.24
74LS30	0.18
74LS31	1.58
74LS32	0.20
74LS33	0.60
74LS37	0.20
74LS38	0.18
74LS40	0.18
74LS42	0.32
74LS44	2.11
74LS47	0.68
74LS48	0.54
74LS49	POA
74LS51	0.22
74LS54	0.28
74LS55	0.44
74LS73	0.35
74LS73A	0.79
74LS74	0.20
74LS74A	0.26
74LS75	0.25
74LS76	POA
74LS76A	1.05
74LS77	0.44
74LS78	0.32
74LS83	0.39
74LS83A	0.39
74LS85	0.36
74LS86	0.26
74LS90	0.32
74LS91	POA
74LS92	POA
74LS93	0.40
74LS95	0.48
74LS96	0.82
74LS107	0.33
74LS107A	0.78
74LS109	0.33
74LS109A	0.66
74LS112	0.33
74LS112A	0.66
74LS113	0.36
74LS113A	0.42
74LS114	0.36
74LS114A	0.40
74LS122	0.33
74LS123	0.35
74LS125	0.28
74LS125A	0.32
74LS126	0.32
74LS126A	0.40
74LS132	0.29
74LS133	0.35
74LS136	0.78
74LS137	1.58
74LS138	0.34
74LS139	0.42
74LS139A	0.42
74LS145	0.66
74LS147	POA
74LS148	0.87
74LS151	0.35
74LS153	0.36
74LS154	1.23
74LS155	0.38
74LS156	0.38
74LS157	0.42
74LS158	0.38
74LS160	0.52
74LS160A	0.60
74LS161	0.46
74LS161A	0.49
74LS162	1.10
74LS162A	1.10
74LS163	0.40
74LS163A	0.64
74LS164	0.40
74LS165	0.50
74LS166	0.50
74LS168	POA
74LS169	0.50
74LS170	POA
74LS173	0.52
74LS173A	0.52
74LS174	0.33
74LS175	0.33
74LS182	POA
74LS183	POA
74LS189	2.81
74LS190	0.54
74LS191	0.49
74LS192	0.54
74LS193	0.48
74LS194	0.54
74LS194A	0.54
74LS195A	0.56
74LS196	POA
74LS221	0.46
74LS224	10.30
74LS240	0.48
74LS241	0.48
74LS242	POA
74LS243	0.50
74LS244	0.48
74LS245	0.50
74LS247	POA
74LS248	POA
74LS249	POA
74LS251	0.00
74LS253	0.00
74LS256	POA
74LS257	0.00
74LS257A	0.48
74LS258	1.00
74LS258A	0.48
74LS259	POA
74LS260	POA
74LS266	POA
74LS273	POA
74LS275	POA
74LS279	0.35
74LS280	0.86
74LS283	0.45
74LS290	POA
74LS292	14.58
74LS293	0.42
74LS294	14.58
74LS295	POA
74LS295A	POA
74LS298	POA
74LS299	1.76
74LS321	3.29
74LS322	POA
74LS322A	POA
74LS323	POA
74LS347	POA
74LS348	POA
74LS352	POA
74LS353	POA
74LS363	POA
74LS364	POA
74LS365	0.53
74LS365A	0.54
74LS366	POA
74LS366A	POA
74LS367	0.36
74LS367A	0.36
74LS368	0.36
74LS368A	POA
74LS373	0.48
74LS374	0.48
74LS375	0.42
74LS377	0.69
74LS378	POA
74LS379	1.50
74LS381A	POA
74LS385	POA
74LS386	POA
74LS390	0.52
74LS393	0.42
74LS395	POA
74LS395A	POA
74LS396	POA
74LS398	POA
74LS399	0.92
74LS423	0.98
74LS445	POA
74LS450	10.68
74LS461A	POA
74LS465	4.18
74LS467	POA
74LS468	POA
74LS469	POA
74LS490	POA
74LS491A	POA
74LS540	0.80
74LS541	0.80
74LS569	POA
74LS573	1.02
74LS574	1.02
74LS590	5.09
74LS592	5.09
74LS593	7.12
74LS595	5.09
74LS597	5.20
74LS621	POA
74LS622	POA
74LS623	POA
74LS624	2.10
74LS625	POA
74LS626	POA
74LS627	POA
74LS628	1.78
74LS629	2.25
74LS631	POA
74LS639	POA
74LS640	POA
74LS640-1	2.79
74LS641	POA
74LS641-1	2.87
74LS642	POA
74LS642-1	POA
74LS643	POA
74LS644	POA
74LS645	0.68
74LS645-1	2.79
74LS646	4.65
74LS652	POA
74LS669	1.58
74LS670	0.78
74LS673	POA
74LS674	16.89
74LS682	2.62
74LS683	POA
74LS684	3.85
74LS685	POA
74LS686	POA
74LS687	POA
74LS688	1.98
74LS693	POA
74LS794	POA
74LS795	POA
74LS796	POA
74LS797	POA
74LS848	POA
81LS95A	1.25
81LS97A	1.25

74HC SERIES

74HC00	0.22
74HC02	0.22
74HC03	0.28
74HC04	0.22
74HCU04	0.24
74HC05	0.32
74HC07	0.48
74HC08	0.22
74HC09	0.48
74HC10	0.29
74HC11	0.22
74HC14	0.26
74HC14A	0.38
74HC20	0.24
74HC21	0.24
74HC27	0.24
74HC30	0.24
74HC32	0.24
74HC42	0.54
74HC51	0.32
74HC58	0.54
74HC73	0.38
74HC74	0.28
74HC74A	0.28
74HC75	0.48
74HC76	0.48
74HC77	0.52
74HC85	0.52
74HC86	0.30
74HC93	0.48
74HC107	0.48
74HC109	0.46
74HC112	0.50
74HC113	0.54
74HC123	0.42
74HC123A	0.42
74HC125	0.42
74HC126	0.45
74HC131	0.52
74HC132	0.60
74HC133	0.44
74HC137	0.72
74HC138	0.34
74HC139	0.32
74HC141	POA
74HC147	0.68
74HC148	0.72
74HC151	0.40
74HC153	0.42
74HC154	0.62
74HC155	0.72
74HC157	0.42
74HC158	0.54
74HC160	0.74
74HC161	0.42
74HC162	0.74
74HC163	0.42
74HC164	0.42
74HC165	0.55
74HC166	0.88
74HC173	0.76
74HC174	0.42
74HC175	0.36
74HC181	1.94
74HC182	0.59
74HC190	0.88
74HC191	0.68
74HC192	0.78
74HC193	0.76
74HC194	0.78
74HC195	0.78
74HC221	0.58
74HC237	0.76
74HC238	0.64
74HC240	0.46
74HC241	0.78
74HC242	0.98
74HC243	0.98
74HC244	0.48
74HC245	0.48
74HC245A	0.54
74HC251	0.36
74HC253	0.52
74HC257	0.52
74HC258	0.73
74HC259	0.52
74HC266	0.48
74HC273	0.54
74HC279	0.58
74HC280	0.92
74HC283	0.76
74HC294	1.29
74HC298	0.78
74HC299	1.38
74HC323	1.82
74HC352	1.20
74HC353	0.75
74HC354	0.84
74HC356	0.84
74HC365	0.52
74HC366	0.62
74HC367	0.52
74HC368	0.56
74HC373	0.48
74HC374	0.48
74HC375	0.78
74HC377	0.52
74HC386	0.38
74HC390	0.48
74HC393	0.41
74HC423	0.54
74HC521	POA
74HC533	0.98
74HC534	0.98
74HC540	0.69
74HC541	0.69
74HC563	0.88
74HC564	0.88
74HC573	0.68
74HC573A	0.86
74HC574	0.64
74HC589	0.92
74HC590	1.20
74HC592	1.24
74HC593	1.89
74HC595	1.14
74HC597	1.10
74HC620	1.82
74HC623	1.48
74HC633	POA
74HC640	1.36
74HC643	1.36
74HC646	1.88
74HC648	1.88
74HC651	1.49
74HC652	2.40
74HC658	POA
74HC659	POA
74HC664	POA
74HC665	POA
74HC670	1.15
74HC677	POA
74HC678	POA
74HC680	POA
74HC682	POA
74HC684	POA
74HC688	0.74
74HC690	1.62
74HC691	1.82
74HC692	1.82
74HC693	1.82
74HC696	1.82
74HC697	1.82
74HC698	1.82
74HC699	1.82
74HC4002	0.48
74HC4015	1.07
74HC4016	0.58
74HC4017	0.60
74HC4020	0.52
74HC4022	0.74
74HC4024	0.62
74HC4028	0.58
74HC4040	0.48
74HC4046	1.44
74HC4046A	1.90
74HC4049	0.46
74HC4050	0.38
74HC4051	0.74
74HC4052	0.74
74HC4053	0.74
74HC4053A	1.12
74HC4060	0.46
74HC4061	POA
74HC4066	0.50
74HC4066A	0.58
74HC4067	4.72
74HC4072	0.48
74HC4075	0.44
74HC4078	0.46
74HC4094	0.78
74HC4316	0.74
74HC4351	1.05
74HC4352	1.62
74HC4353	1.62
74HC4511	0.84
74HC4514	1.10
74HC4515	1.85
74HC4518	0.87
74HC4520	0.78
74HC4534	POA
74HC4538	0.68
74HC4543	0.98
74HC7001	1.01
74HC7007	0.42
74HC7032	POA
74HC7074	POA
74HC7240	0.98
74HC7241	0.98
74HC7244	0.98
74HC7266	0.66
74HC7292	1.10
74HC7294	1.10
74HC7640	1.98
74HC7643	1.98
74HC7645	1.98
74HC40102	1.32
74HC40103	1.12
74HC40105	1.42

74HCT SERIES

74HCT02	0.24
74HCT03	0.28
74HCT04	0.24
74HCT08	0.24
74HCT10	0.24
74HCT11	0.24
74HCT14	0.28
74HCT20	0.28
74HCT21	0.28
74HCT27	0.28
74HCT30	0.28
74HCT32	0.28
74HCT42	0.48
74HCT73	0.38
74HCT74	0.28
74HCT75	0.38
74HCT85	0.54
74HCT86	0.38
74HCT93	0.60
74HCT107	0.40
74HCT109	0.42
74HCT112	0.42
74HCT123	0.64
74HCT125	0.56
74HCT126	0.54
74HCT132	0.50
74HCT137	0.54
74HCT138	0.32
74HCT139	0.52
74HCT147	0.70
74HCT151	0.52
74HCT153	0.52
74HCT154	1.20
74HCT157	0.45
74HCT158	0.50
74HCT160	0.54
74HCT161	0.54
74HCT162	0.84
74HCT163	0.54
74HCT164	0.52
74HCT165	0.52
74HCT166	0.52
74HCT173	0.52
74HCT174	0.52
74HCT175	0.52
74HCT181	3.24
74HCT182	1.20
74HCT190	0.62
74HCT191	0.59
74HCT192	1.20
74HCT193	0.62
74HCT194	1.20
74HCT195	1.20
74HCT221	0.66
74HCT237	1.20
74HCT238	0.69
74HCT240	0.53
74HCT241	0.58
74HCT242	1.24
74HCT243	1.24
74HCT244	0.54
74HCT245	0.54
74HCT251	1.11
74HCT253	1.11
74HCT257	1.11
74HCT258	1.11
74HCT259	1.24
74HCT273	1.24
74HCT280	1.29
74HCT283	0.64
74HCT297	1.48
74HCT299	1.68
74HCT354	0.74
74HCT356	1.54
74HCT365	1.28
74HCT366	1.34
74HCT367	0.59
74HCT368	1.29
74HCT373	0.52
74HCT374	0.52
74HCT377	0.65
74HCT390	0.68
74HCT393	0.68
74HCT394	POA
74HCT423	0.82
74HCT533	1.63
74HCT534	0.75
74HCT540	0.66
74HCT541	0.74
74HCT563	1.46
74HCT564	1.67
74HCT573	0.74
74HCT574	0.74
74HCT583	1.48
74HCT597	1.52
74HCT640	1.34
74HCT643	1.97
74HCT646	2.40
74HCT648	6.40
74HCT651	POA
74HCT652	POA
74HCT670	1.10
74HCT673	POA
74HCT688	1.10
74HCT4002	0.39
74HCT4015	1.41
74HCT4016	0.52
74HCT4017	0.68
74HCT4020	0.74
74HCT4024	0.68
74HCT4040	0.70
74HCT4046	2.10
74HCT4051	0.96
74HCT4052	0.96
74HCT4053	0.84
74HCT4059	2.24
74HCT4060	0.84
74HCT4066	0.66
74HCT4067	5.78
74HCT4075	0.36
74HCT4094	0.84
74HCT4316	0.68
74HCT4351	1.04
74HCT4510	1.54
74HCT4511	0.94
74HCT4514	1.64
74HCT4515	3.81
74HCT4516	POA
74HCT4520	0.90
74HCT4538	1.02
74HCT7007	0.39
74HCT7038	5.40
74HCT7046	2.80
74HCT40102	2.43
74HCT40103	1.48
74HCT40104	POA

74HC SERIES SURFACE MOUNT

74HC00M	0.32
74HC02M	0.32
74HC03M	0.32
74HC04M	0.32
74HCU04	0.32
74HC08M	0.32
74HC10M	0.32
74HC14M	0.36
74HC20M	0.36
74HC30M	0.36
74HC32M	0.36
74HC74A	0.36
74HC75M	0.34
74HC85WM	0.65
74HC86M	0.36
74HC123AM	0.46
74HC125M	0.46
74HC132M	0.42
74HC138M	0.38
74HC139M	0.38
74HC154WM	0.64
74HC157M	0.38
74HC161M	0.48
74HC164M	0.48
74HC165M	0.57
74HC173M	0.48
74HC174M	0.38
74HC221AM	0.65
74HC240WM	0.55
74HC244WM	0.55
74HC245AW	0.62
74HC251M	0.42
74HC259M	0.69
74HC273WM	0.55
74HC367WM	0.53
74HC373WM	0.55
74HC374WM	0.55
74HC390M	0.57
74HC393M	0.53
74HC540WM	0.76
74HC541WM	0.76
74HC573WM	1.09
74HC574WM	0.84
74HC688WM	0.84
74HC4017M	0.48
74HC4020M	0.48
74HC4040M	0.44
74HC4046M	1.68
74HC4060M	0.48
74HC4066W	0.84

74F SERIES

74F00	0.28
74F02	0.28
74F04	0.28
74F06	0.74
74F07	0.74
74F08	0.28
74F10	0.28
74F11	0.28
74F13	POA
74F14	0.36
74F20	0.39
74F27	0.41
74F30	0.28
74F32	0.28
74F37	0.51
74F38	0.44
74F40	0.94
74F51	0.94
74F64	1.24
74F74	0.31
74F85	2.24
74F86	0.34
74F109	0.58
74F112	0.63
74F113	POA
74F114	POA
74F125	0.56
74F126	POA
74F132	0.58
74F138	0.58
74F139	0.58
74F148	POA
74F151	1.47
74F153	0.58
74F157	0.58
74F158	0.80
74F160	0.90
74F160A	POA
74F161	0.88
74F162	POA
74F163	0.88
74F164	0.88
74F166	3.82
74F168	POA
74F169	3.60
74F174	0.80
74F175	0.80
74F181	6.85
74F182	POA
74F189	4.40
74F190	POA
74F191	2.92
74F192	POA
74F193	2.92
74F194	1.36
74F195	2.00
74F219	POA
74F224	POA
74F240	0.60
74F241	0.60
74F244	0.60
74F245	0.66
74F251	POA
74F251A	0.75
74F253	POA
74F257	POA
74F257A	0.56
74F258	POA
74F259	POA
74F260	0.76
74F269	5.54
74F273	0.96
74F280	0.70
74F283	1.00
74F299	POA
74F323	POA
74F350	POA
74F352	POA
74F353	POA
74F365	POA
74F366	POA
74F367	1.42
74F368	POA
74F373	0.60
74F374	0.60
74F377	1.34
74F378	2.72
74F381	5.70
74F385	POA
74F395	POA
74F399	POA
74F412	POA
74F413	POA
74F432	POA
74F521	1.05
74F524	POA
74F533	POA
74F534	POA
74F537	POA
74F538	POA
74F539	POA
74F540	POA
74F541	1.98
74F543	3.57
74F544	POA
74F545	POA
74F547	POA
74F573	2.78
74F574	2.78
74F579	6.59
74F604	5.59
74F620	POA
74F621	POA
74F623	POA
74F646	3.90
74F676	3.22
74F821	POA
74F823	POA
74F825	POA
74F827	3.32
74F841	3.51

74AC SERIES

74AC00	0.38
74AC02	0.49
74AC04	0.40
74AC08	0.40
74AC10	0.40
74AC11	0.40
74AC14	0.40
74AC20	0.40
74AC32	0.40
74AC74	0.48
74AC109	0.64
74AC112	0.81
74AC138	0.65
74AC139	0.65
74AC151	0.68
74AC153	0.65
74AC157	0.81
74AC158	0.65
74AC163	0.80
74AC169	1.98
74AC174	0.65
74AC175	0.80
74AC191	1.38
74AC240	0.92
74AC241	0.92
74AC244	0.92
74AC245	1.10
74AC251	0.60
74AC253	0.60
74AC258	0.60
74AC273	1.10
74AC283	1.40
74AC299	2.06
74AC373	0.94
74AC374	0.92
74AC377	0.98
74AC521	POA
74AC540	0.98
74AC541	0.98
74AC573	1.38
74AC574	1.38
74AC646	POA
74AC648	POA

74C SERIES

74C00	0.50
74C02	0.50
74C08	0.50
74C10	0.50
74C14	POA
74C20	0.50
74C30	0.50
74C32	0.50
74C42	1.78
74C48	1.84
74C73	1.68
74C74	0.89
74C76	1.14
74C85	1.66
74C90	1.16
74C93	1.63
74C150	3.48
74C151	POA
74C154	4.88
74C157	3.02
74C164	1.91
74C221	2.54
74C240	1.38
74C244	1.38
74C373	1.38
74C374	1.38
74C901	0.94
74C902	0.94
74C903	POA
74C906	0.94
74C907	0.94
74C908	1.51
74C911	13.98
74C912	13.98
74C914	0.94
74C915	2.24
74C922	5.60
74C923	6.28
74C925	8.40
74C926	8.40
74C929	POA
80C95	0.76
80C98	0.98

74S SERIES

74S00	0.68
74S02	0.68
74S03	0.78
74S04	0.68
74S08	0.68
74S09	0.68
74S10	1.10
74S11	0.68
74S20	0.68
74S32	0.68
74S38	0.68
74S40	0.25
74S51	0.36
74S64	0.36
74S74	0.83
74S86	0.83
74S112	0.90
74S124	3.13
74S132	1.11
74S133	0.80
74S134	2.15
74S138	0.97
74S139	0.97
74S140	1.02
74S153	1.39
74S157	1.89
74S163	2.79
74S174	1.01
74S175	1.49
74S182	3.62
74S189	2.35
74S195	2.64
74S240	2.31
74S241	2.31
74S244	1.95
74S257	1.34
74S258	1.34
74S260	0.77
74S273	2.68
74S274	2.66
74S280	1.06
74S283	2.09
74S374	2.31
74S394	2.31
74S412	2.31

VOLTAGE REGULATORS

78008AP	1.34
7805	0.44
7805A	0.68
7805FA	0.98
7806	0.88
7808	1.34
7809	1.34
7812	0.68
7812A	0.98
7815	0.68
7818	1.12
7824	1.12
78L05	0.28
78L05A	0.28
78L12	0.28
78L12A	0.28
78L15	0.28
78L24	0.28
78L56	1.10
78M05	0.70
78M05A	0.70
78M12	0.70
78M12A	0.70
78M13A	1.40
78M15	0.78
78S05	1.10
78S12	1.10
78S15	1.10
7905	0.68
7905A	0.98
7905FA	0.68
7909	0.98
7912	0.68
7912A	0.98
7912FA	0.98
7915	0.68
7918	1.60.
7924	1.60
79L12A	0.28
79M05	0.98
79M05A	1.82
79M12	1.82
79M12A	1.82
L4805CV	3.40
L4940V5	6.40
LM317MP	0.98
LM317T	0.78
LM338K	4.45
LT1084CT5	6.92
LT1085CT5	6.60
RC4195N	2.40
TL783CKC	6.98

DIODES

1N2986RB	18.20
1N3881	2.54
1N3997A	6.55
1N4001	0.04
1N4002	0.04
1N4003	0.04
1N4006	0.04
1N4007	0.04
1N4148	0.03
1N4149	0.06
1N4150	0.08
1N4446	0.06
1N4728A	0.24
1N4735A	0.24
1N4736A	0.24
1N4740A	0.24
1N4743A	0.24
1N4744A	0.24
1N4756A	0.24
1N5226B	0.09
1N5232B	0.09
1N5234B	0.09
1N5337B	0.48
1N5349B	0.48
1N5352B	0.48
1N5357B	0.48
1N5365B	0.48
1N5366B	0.48
1N5370B	0.48
1N5380B	0.48
1N5401	0.11
1N5402	0.11
1N6287A	1.55
1N825	2.75
1N825A	2.75
1N827	3.14
1SS252	0.20
5082-2800	0.66
5082-2810	1.40
5082-2835	0.44
AA119	0.60
AA144	0.72
AAZ15	0.58
AAZ17	0.58
AAZ18	0.48
BAV10	0.08
BAV45	4.98
BAW62	0.06
BAX16	0.06
BB204	0.32
BB212	2.48
BB405B	0.22
BB809	0.60
BY179	0.42
BY260-200	3.58
BY261-200	3.98
BYV28-100	0.99
BYV32-50	1.60
CV8805	0.60
DS16C	0.40
MV1404	15.90
MV209	1.20
OA200	0.10
OA202	0.20
OA47	0.14
OA90	0.14
P6KE36A	0.88
P6KE47A	0.88
REC53A	0.40
ZPD2.7V	0.06

ZENER DIODES MISC.

BZY93C7V5	6.60
BZY93C15	6.60
BZY93C18R	6.60
BZY93C20	6.60
BZY93C24V	6.60
BZY93C33R	6.60
BZT03C120	0.74
BZX61C9V2	0.09
BZX61C24V	0.09

ZENER DIODES 400mW
2.4V to 75V
Price: 6p each

ZENER DIODES 500mW
2.4V to 200V
Price: 6p each

ZENER DIODES 1.3 WATT
2.7V to 200V
Price:10p each

ZENER DIODES 3.0 WATT
7.5V to 270V
Price:74p each

ZENER DIODES 5.0 WATT
3.3V to 200V
Price:42p each

ZENER DIODES STUD MOUNT 20 WATT
7.5V to 75V
Price: £4.94 ea.

BRIDGE RECTIFIERS

0.9A/200VDIL	0.38
3.0A/200V SIL	0.57
6A/100V SIL	1.60
8A/200V SIL	1.96
35A/100V/Sqr	2.98
KBPC1002	1.64
KBPC3502	2.98
W005-1A/50V	0.32
W02G-1.5A	0.40
2W02	0.40
2KBB10R/SIL	0.66
2KBB20R/SIL	0.70
B80C1500/Sqr	0.35
B80C1500SIL	0.60
SKB6008/60A	POA
SKD6008/60A	POA

CRYSTALS

HC49(HC18/U)

Freq.MHz	
1.843200	1.60
2.000000	1.66
2.453200	9.96
2.457600	1.49
3.276800	0.98
3.579545	1.10
3.686400	1.02
4.000000	1.02
4.096000	1.10
4.194304	1.10
4.433619	1.10
4.608000	1.10
4.915200	1.20
5.000000/S	1.02
5.068800	1.10
5.242880	1.20
5.888200	1.80
6.000000	1.02
6.144000	1.02
6.400000	1.64
6.552000	1.40
6.553600	1.21
7.372800	0.78
8.000000	1.00
8.867230	1.34
9.830400	1.20
10.00000	1.10
10.69500	1.90
11.00000	1.10
12.00000	0.92
13.87500	2.40
14.00000	1.64
14.31818/S	0.85
14.74560/S	1.10
14.74560	1.10
15.00000/S	1.10
16.00000	1.02
16.00000/S	1.20
18.43200/S	1.10
19.66080/S	1.20
20.00000/S	1.60
22.11840/S	1.68
24.00000/S	1.82
27.64800/S	1.20
30.00000/S	6.99
32.00000/S	1.40
48.00000/S	1.68

S = Series

HC33/U

0.204800	8.23
0.307200	6.99
1.000000	3.95
1.843200	3.71
2.000000	4.65
2.097152	3.71
2.457600	1.92
2.500000	1.92
3.000000	2.25

HC49/U4H

3.276800	1.66
3.579545	1.58
5.068800	2.25
7.864320	1.49
8.000000	1.14
10.00000	2.25
11.05920	2.40
12.00000	1.14
14.00000	2.25
16.00000	1.14
20.00000	1.52
24.00000	1.90

UM-1

8.000000	2.25
8.192000	2.02
10.00000	2.25
11.00000	2.25
12.28800	2.66
15.00000	2.25
17.73447	2.80
18.00000	2.50
20.00000	2.25
21.00000	2.25
24.00000	2.80

CRYSTALS MISC.

HC43/T 1.000000	6.99
MINI CYLINDER 0.032768	0.88
WATCH 0.032768	0.82

CRYSTAL OSC. MODULES

8pin DIL Plastic pkg TTL Output
4 Pins spaced at corners of 8pinDIL
Freq.= MHz
4, 4.9152, 8, 10, 12, 16 & 20MHz
Price: £3.66 ea.
24,32,40&50MHz
Price £3.94 ea.

8pin DIL Sealed Metal Package HCMOS Output

13.2mm sq.
Pins spaced at corners of 8pinDIL
Freq.= MHz
3.6864,8,10,12MHz
Price: £4.88 each

16,20,24,32,40&50MHz
Price: £3.84 each

TTL Output 14pin DIL Layout Sealed Metal 4pin Pkg
Freq.= MHz
1MHz £8.90 ea.

4,4.9152,6,8,9.8304, 10,12,15,16, 18.432, 19.6608, 20, 24, 25 & 30MHz
Price: £3.52 ea.

32, 32.768, 33.33, 40 & 50, 66MHz
Price: £4.45 ea.

Programmable Crystal Oscillators

EXO-3C SERIES 8pin DIL Plastic Package
Freq.= MHz
12, 14.31818, 16, 16.384,19.6608 & 20MHz
Price: £3.92 ea.

16pin DIL Plastic Package
Programmable for 57 Diff.Frequency

SPG8640AN
0.005 to 600kHz

SPG8640BN
0.0083 to 1MHz

SPG8640CN
0.0064 to 768kHz
BaudRateGenerator

SPG8650BN
0.00083 to 100kHz

PXO-600
0.005 to 600kHz

PXO-1000
0.0083 to 1MHz
All above
Price: £ 9.25 ea.
SPG8651BN
0.00083 to 100kHz
Cal. Tol. 5ppm
Price: £ 10.50 ea.

DC to DC Converters

TDK CE-0344	5.60
3W5R 15-15	27.50
IPL S.010	23.40

1 Watt DC/DC 5V Input ±Output DIL & SIL by Newport
NMA0505±5V
NMA0509±9V
NMA0512±12V
NMA0515±15V
Price: £ 8.85ea.

DC/DC Converters by Computer Products

PM623	24.60
PM671	26.70
PM672	26.70
PM903	44.00
PM951	46.50

RESISTORS

METAL FILM
0.25W 1%
E24 Series
10R to 1M
Pack of 5 = 15p
Pack of 10 = 25p

METAL FILM PRECISION
0.25 WATT 0.1%
E96 Series
100R to 255K
Price: £0.94 each

HIGH PRECISION NON-INDUCTIVE WIRE WOUND 0.15 WATT 0.1%
Temp.Coeff.3ppm
10R,50R,100R,250R, 10K,100K
Price: £3.85 each

HIGH PRECISION NON-INDUCTIVE WIRE WOUND 0.33 WATT 0.1%
Temp.Coeff.3ppm
1R,5R,10R,20R,50R
Price: £3.60 each

100R,120R, 250R, 500R,1K, 2K, 5K, 10K,20K
Price: £3.10 each

MEMORIES

DYNAMIC RAM

4164-10	1.40
4164-12	1.20
4164-15	1.20
41256-8	2.40
41256-10	2.40
41256-12	2.40
41264-15	2.24
41464-12	4.45
41464-10	4.45
4464-10	2.80
414256A-70	3.90
44C256AZ-10	6.95
511000-85	8.45
HM48416AP-15	4.60
HM48416AP-20	4.25
HY53C256LS-80	POA
HY53C464LS-80	POA
HYB511000-85	8.45
KM44C256AZ-10	6.95
M5M4464P-15	4.60
MK4116N-54	2.80
MK4564N-15	1.20
NMC3764N-15	1.60
UPD41464C-12	4.20
UPD41464C-15	4.20
UPD416C-2	3.40
UPD416C-3	3.65
UPD446D-1	2.60

STATIC RAM

2114-3L	3.40
6264LP-10	2.40
6264LP-12	2.40
62256LP-12	4.95
62256LP-10	4.95
CDM6116AE3	5.30
CDM6117AE3	5.85
HM1-6116-5	4.38
HM3-6116-5	3.60
HM6116LP-2	2.60
HM6116LP-3	2.60
HM6117LP-3	5.75
HM62256LP-10	7.93
HM6264ALP-12	3.95
HM6264ASP-20	3.95
HM6267P-35	5.07
HM628128LP-80	18.55
HM66204L-12	15.80
KM62256ALP-10	4.95
LH5164D-10L	2.40
PCD5101P	3.30
UPD43256AGU10L	8.33
UPD43256C-12	5.60
UPD4364C-15	4.70

UVPROMS

27C128-25	3.95
27C64A-15	3.95
27C256-15	3.95
27C256-25	3.95
27C512D-12	6.48
27C1000D-12	8.92
27C4096-12	POA
HM27C101G-20	9.80
HN27C1024HG10	16.63
HN27C64FP-20T	3.40
HN27C64G-15	4.20
HN27C64G-20	4.20
HN462532P	4.50
HN4827128G-25	4.55
HN482764G	3.80
M2716-1F1	3.50
M5L2732K	4.40
M5L2764K	3.30
MBM27C64-20/21V	4.90
MBM27C128-30	4.20
MBM27C256-30	5.10
NMC27C256Q-25	4.95
NMC27C64Q-25	3.66
TMS2516JL-45	4.58
TMS27128JL-25	4.60
TMS2716JL-45	4.60
UPD27256D/21V	5.60
UPD2732A/21V	4.95
UPD27C256D-15	5.80
UPD27C512D-15	6.96
UPD27C64D-25	4.95

EEPROMS

28C64-25	9.80
28C64-15	10.95
28C256-20	18.40
28C256-15	19.60
28C256-15DC	28.50
X2816AD	5.10
X2816AP-25	5.10
X2864AP-35	12.20
24C01	1.62
24C02	2.10
24C04	2.98
24C16	5.40
28C04A-20	4.40
59C11	1.44
93C06	1.12
93C46	1.28
93C56	1.52
93C66	2.16

MISC. MEMORIES

6341-1J	4.58
AM2148-45DC	5.44
AM27S281PC	3.98
IDT7130LA-100P	10.40
IDT7132LA-100P	12.20
MB8414E	4.95
MCM4027AC3	2.80
N82S09N	POA
N82S126AN	2.49
N82S153N	5.80
N82S181AN	6.09
NMC6504J-9	3.40
NMC9306N	1.45
P5101L-1	3.90
TBP18S030N	1.74
TBP24S10N	2.90
TBP24SA10N	3.15
TC5501P	3.50
TC5504AP-2	3.40
TC5517AP-2	4.20
TC5565PL-15	3.60
TMS4014JDL	3.40

RESISTORS SMD

0R0 to 3M3
Case 1206-Pack of 5
Price: £0.30 per pk.

CAPACITORS SURFACE MOUNT

Multilayer Ceramic
63 VOLT
Case Size: 1206
L2xW1.25mm

10pF,22pF,33pF,47pF
100pF,220pF,330pF
470pF,1000pF,2200pf
3300pF,4700pF
10000pF, 22000pF
33000pF
Price: 15p each

47000pF 100000pF
Price: 18p each

MICROPROCESSOR & SUPPORT ICs

100114DEC	7.40
100141DC	9.80
6303XP	8.76
6321P	4.41
63485CP32/SM	19.95
63B03XP	10.07
6502	3.76
6502A	3.98
6520P	4.40
6522	4.40
6522A	5.32
6551	4.43
6551A	5.20
65C02P2	6.54
65C02P3	7.16
65C102P2	6.78
65C22P2	6.51
65C51E-1	5.60
65C51E-2	6.20
68000CP-12	9.65
68000CP-8	6.78
68000P-10	7.41
68000P-16	18.20
68008P-8	9.85
6800P	5.70
68010P-12	POA
6802P	3.90
6803P	7.98
6805E3E	14.75
6809P	4.98
6810P	POA
6821P	1.68
6840P	3.22
6844P	17.20
6845P	4.86
6845SP	4.86
68A09P	4.60
68A21P	1.98
68A40P	2.56
68A50P	2.98
68B00P	7.68
68B09P	4.73
68B21P	2.56
68B40P	3.20
8080A	POA
8085AH-2	5.98
8086	11.92
8086-2	11.92
80C286-8/PLCC	24.40
80C32-16MHZ	6.98
80C32P	4.28
80C85A	5.91
80C85A-2	6.97
8118-5CH	7.60
82C54-2	4.10
93L34DC	7.08
AM25LS2568P	2.68
AM25LS2569P	2.68
AM2602PC	POA
AM26LS31DC	2.30
AM26LS31PC	1.26
AM27S191ADC	10.20
AM27S281PC	9.82
AM2964BDC	12.36
AM2965DC	10.68
AM2966PC	4.97
AM29826DC	5.98
AM685DL	9.82
AM8238PC	5.60
AM9050CDC	4.95
AM9050CPC	4.60
AM9102CPC	2.82
AM9114BDM	9.96
AM9551PC	9.66
AM96L02PC	3.35
AY-5-8136	6.45
AY-5-8136-006	6.45
C1164/SMD	4.98
C8231A	59.00
C8253	3.80
CA80C85B	5.98
CD82C85	9.62
CD82C86H-5	9.74
CDP6818AE	8.32
COM8136	6.45
COM81C17	9.41
CP82C54	6.42
CRT-8004-001	9.65
CS8205	8.92
D3232	6.86
D8086	11.92
D8086-2	11.92
D8202A	POA
D8254-2	6.42
D8284A	3.90
D8288	6.48
D82C284-12	9.60
D82C284-8	7.85
D82C288-10	10.96
D82C288-12	11.85
D82C288-8	9.36
D8748H	10.26
DP8228N	6.83
DP8238N	6.72
DP8304BN	2.94
DP8311N	8.51
DS1221	8.11
DS1231-20	5.50
DS1232	4.12
DS3486N	1.74
DS3487N	1.74
DS34C86N	2.94
DS34C87N	2.94
DS3631N	4.35
DS3632N	3.44
DS3633N	3.92
DS3634N	3.44
DS3691N	3.04
DS3862N	16.98
DS5000-32-12	3POA
DS8640N	1.71
DS8820AN	1.92
DS8832N	3.98
DS8836N	2.88
DS8837N	2.83
DS8838N	2.75
DS9636A	1.98
DS9637A	1.68
DS9638A	1.68
DS9639A	1.98
EF6821P	1.68
EF6850P	1.68
EF68B09EP	5.35
EF68B09P	4.73
EF68B21P	2.56
EP610PC-35	POA
HD1-0165-5	10.96
HD146818AP	4.41
HD3-6402-9	6.16
HD3-6440-9	8.89
HD3-6495-9	8.89
HD44883	POA
HD46505SP	POA
HD46802P	POA
HD6321P	4.41
HD63485PS32	32.50
HD63B03XP	11.74
HD68000P8	11.59
HD6803P	7.98
HD6845SP	4.86
HD68A52P	POA
HD68B21P	3.53
HI3-7159-5	20.98
HI3-7159A-5	23.40
HM10422	14.30
ID82C86H	17.06
IM6402AIPL	10.20
IM6402IPL	7.75
IM6403IPL	12.92
IMS2600P-15	4.98
INS8250N	7.80
INS8250N-B	7.80
M5M82C51AP	5.89
M5M82C54P-6	6.57
MAB8031AH12P	4.23
MAB8035HL-6P	5.98
MC10103P	2.89
MC10115L	3.85
MC10115P	2.89
MC146805E2P	8.53
MC68000P12	POA
MC68000P16	18.20
MC68010P10	POA
MC68010P12	POA
MC6802P	3.95
MC6821P	1.99
MC6840P	5.05
MC6844P	18.40
MC6845P	7.38
MC6850P	3.35
MC68705R3P	25.35
MC68A00P	7.02
MC68A09P	7.62
MC68HC05E0FN	11.96
MC8314P	6.60
MCM6810P	4.98
MCM68A10P	7.42
MM53200N	4.73
MM58167BN	13.65
MM58174AN	14.82
MM58274CN	9.59
MSM5832RS	5.11
MSM80C35RS	4.90
MSM80C39/SMD	6.45
MSM80C39RS	7.55
MSM80C85A	5.91
MSM80C85A-2	5.98
MSM80C86	7.60
MSM81C55	4.60
MSM82C51A	4.87
MSM82C53-2	5.38
MSM82C53-5	5.38
MSM82C54-2	4.20
MSM82C55A2RS	5.18
MSM82C59A-2	3.98
MSM82C84A	4.42
MSM82C84A-2	4.95
MSM82C88	12.60
N80C286-10/PL	24.50
N80C286-12/PL	29.54
N80L286-8C2	36.20
N8235N	3.68
N8264N	3.68
N82S126AN	5.88
N82S181F	10.04
NS16450N	5.98
NS16550AFN	12.60
NSC800N-1	10.80
P8032AH	4.62
P8051AH	11.20
P8052AH/BASIC	24.99
P8080A	POA
P8085A-2	5.92
P8085AH-2	6.88
P8088	6.80
P80C31BH	6.26
P80C32/INTEL	8.30
P80C51FA	16.82
P80C86AL-2	12.60
P8155H/2	6.98
P8205	2.00
P8212	2.40
P8226	2.40
P8251A	4.05
P8253	4.70
P8255A-5	3.90
P8259	2.85
P8259A	4.05
P8274	16.71
P8279-5	3.20
P8282	2.64
P8286	3.60
P82C54-2	6.98
PAL10L8CN	1.90
PAL12H6CN	1.90
PAL16R4-15CN	2.98
PAL16R4BCN	2.17
PAL20L10CNS	4.35
PAL20X8CNS	3.32
PCD8584P	12.22
PCD8584T	12.22
PCF8566P	8.28
PCF8566T	8.28
PCF8570P	8.63
PCF8573P	9.64
PCF8574P	7.68
PCF8574T	7.68
PCF8591P	12.26
PIC16C54RC/P	3.60
PIC16C55RC/P	4.48
PIC16C56RC/P	4.42
PIC16C57RC/P	5.06
PIC16C64-04/P	13.98
PIC16C64-20P	23.85
PIC16C64-JW	30.96
PIC16C71-16P	8.94
PIC16C84-10/P	12.24
PIC17C42-16JW	35.51
R6502AP	5.91
R6520P	4.40
R6522	4.40
R6522AP	5.32
R65C02P2	6.54
R65C02P3	7.16
R65C02P4	8.95
R65C102P2	6.78
R65C21P2	5.46
R65C22P2	6.51
SAB80C32-16	6.98
SAB80C32P	4.28
SAB80C535-N	12.24
SAB8155-P	3.82
SAB8259AP	3.59
SAB82C54-2-P	4.12
SAB82C55A-2-P	4.80
SC80C451CCN64	13.60
SC87C51CCF40	31.50
SC87C51CCG40	31.95
SCN2661BC1N28	POA
SCN2661CCN28	POA
TL16C552FN	POA
TMP7002NL-2	4.97
TMP8085AP-2	5.98
TMS320C10NL	9.32
TMS320C25FNL	17.23
TMS320C25GBL	70.58
TMS3477NL	6.68
TMS3700NSB	8.78
TMS3702ANS	8.78
TMS3835ANS	7.55
TMS77C01NL	10.74
TMS9900NL	24.40
TMS9901NL	14.16
TMS9902ANL	15.94
TMS9914ANL	23.10
TMS9928ANL	7.40
TMS9995JDL	69.85
UA9636ACP	2.66
UA9637A	2.38
UA9638CP	2.66
UA9639CP	2.38
UM6845B	4.95
UM9151	POA
UM9151-3	POA
UPB8238	POA
UPB8282C	4.98
UPB8284AD	4.98
UPB8286C	4.98
UPD70108C-10	9.10
UPD70108C-8	6.95
UPD70116C-10	12.90
UPD70116C-8	9.20
UPD71055C	4.77
UPD7201AC	6.93
UPD7201C	6.12
UPD765AC	5.42
UPD780C-1	4.76
UPD80C39HC	8.42
UPD8155HD	5.84
UPD8251AFC	4.08
UPD8253C-2	3.98
UPD8253C-5	3.98
UPD8286C	POA
UPD8741AD	12.52
UPD8749HC	14.74
V20-10MHZ	9.10
V20-8MHZ	6.95
V30-10MHZ	12.90
V30-8MHZ	9.20
V61C30P	7.80
VC0106N6	8.60
X68HC05EOFN	11.96
Z0800110PSC	16.90
Z0868112PSC	3.20
Z180-MPU	POA
Z8001B-CPU	11.96
Z8018008VSC	8.25
Z80A-CPU	2.79
Z80A-CPU/cmos	3.97
Z80A-CTC	2.98
Z80A-DART	4.94
Z80A-DMA	5.40
Z80A-PIO	2.60
Z80A-SIO/0	4.76
Z80B-CPU	2.60
Z80B-CPU/CMOS	4.66
Z80B-CTC	3.02
Z80B-DART	4.93
Z80B-DMA	POA
Z80B-PIO	3.00
Z80B-SIO/0	4.92
Z80C00AB6	3.38
Z84C42 CMOS	6.60
Z8681-B1	6.79

TELECOM & SPECIAL FUNCTION ICs

62X0890-U18	3.70
707W02020	5.25
733W00124	5.25
AMA1503GXB	4.68
BAA1505/Plessey	2.20
CLA25106/PLCC	5.95
GA05001GDB	3.20
KR9600P	11.72
KS-49258/PLCC	5.92
MJ1454BB	7.65
MK5175N	3.80
OC-147-7	2.40
PBD352303	6.40
PP34C108	6.80
Q4704	3.60
QMV16BP5	7.98
QMV18C	6.95
QMV18CN1	7.85
QMV18CW1	7.85
QMV25C	8.42
QMV62AW1	6.90
S4534-AMI	4.20
SA336931	3.20
SCM66115P	4.98
SGS7P050	4.55
SP1450B	5.76
ULA1RB029E1	6.80
ULA20RK008E15	9.72
XR-T5683	3.60
ZNA2L029J-BS	3.80
ZNPCM1J-BS	8.95

LINEAR & MISCS.

3630BM/BB	3.40
49620/BB	POA
555-TIMER	0.40
6341-1J	POA
741-OPAMP	0.18
AD520JN	POA
AD524	21.52
AD534JH	48.27
AD537JH	POA
AD548JN	2.06
AD574AKD	54.57
AD578JN	POA
AD581JH	8.92
AD581KCSA	9.97
AD585AQ	31.55
AD592CN	POA
AD594AD	16.80
AD595AD	15.24
AD648JN	3.09
AD707JN	3.65
AD711JN	2.61
AD712JN	3.57
AD7245JN/KN	POA
AD736JN	8.21
AD741KN	3.69
AD7523KN	9.80
AD7537JN	38.04
AD7537LN	POA
AD7542KN	39.35
AD7543JCWE	POA
AD7578KN	50.81
AD844AN	9.71
ADC0804LCN	3.98
ADC804LCWM	12.10
ADC0820CCN	19.93
ADC0834CCN	10.80
ADC84KG-10	38.98
ADC908HP	18.42
ADDAC80N	POA
ADG201AKN	7.59
ADOP07CN	1.92
AH0015CD	17.20
AY-3-1270	3.60
AY-5-1013	4.60
AY-5-1013A	5.98
AY-5-1250	POA
AY-5-3600-PRO	9.96
BA6109	1.68
BA6208	1.40
CA3046	0.54
CA3046(SMD)	0.89
CA3054	1.68
CA3059	2.10
CA3078AT	3.84
CA3079	1.20
CA3080E	0.60
CA3081	1.14
CA3089E	1.68
CA3094AE	2.16
CA3096E	3.64
CA3097E	2.60
CA3120E	POA
CA3130BT	19.20
CA3130E	0.81
CA3140AE	1.60
CA3140E	0.42
CA3146E	0.98
CA3160E	1.49
CA3240E	1.27
CA3240E1	3.00
CA3260E	3.04
CA3280AE	5.94
CA3280E	3.42
CA555CE	0.40
CA741CE	0.18
CS5503-KD	POA
CX7925B	POA
D169CJ	POA
DAC0800LCN	3.40
DAC0832LCN	5.60
DAC08CP	3.53
DAC08EP	4.65
DAC1008LCN	10.73
DAC1222LCN	20.40
DF1700P	17.91
DG201ABK	3.83
DG211CJ	1.36
DG508ACJ	3.47
DG508CJ	3.25
DS1488N	0.80
DS14C88M/SMD	1.65
DS14C88N	1.47
DS14C89AN	1.47
HA12017	1.55
HA13426	11.96
HA17723	1.40
HD75189P	0.80
HEF4754V	POA
HI1-0201-5	6.43
HI1-508A-5	11.21
HI1-549-5	POA
HI1-574AKD-5	42.50
HI3-0201-5	3.95
HI3-0509A-5	POA
HIIL1	2.40
HS574-AK	18.20
ICL7104-16CPL	26.08
ICL7106CPL	3.60
ICL7107CQH	5.20
ICL7109CPL	10.94
ICL7116CPL	8.53
ICL7117CPL	11.02
ICL7126CPL	11.02
ICL7135CPI	12.19
ICL7136CPL	11.02
ICL7137CPL	11.02
ICL7606CJN	12.24
ICL7611DCPA	1.41
ICL7621DCPA	1.98
ICL7622	POA
ICL7650CPD	5.68
ICL7650SCPD	5.85
ICL7652BCPD	8.24
ICL7652CPD	8.24
ICL7660CPA	2.88
ICL7660SCPA	2.96
ICL7662CPA	3.35
ICL7663BCJA	6.78
ICL7663BCPA	5.10
ICL7664CPA	7.95
ICL7665ACPA	4.47
ICL7673CPA	1.26
ICL8052ACPD	8.73
ICL8068AJD	16.49
ICL8069CCSQ	4.09
ICL8069DCSQ	2.83
ICL8069DCZR	2.21
ICL8211CPA	1.49
ICL8212CPA	2.74
ICM7170IPG	8.14
ICM7207AIPD	10.35
ICM7207IPD	7.94
ICM7209IPA	6.99
ICM7211AMIPL	5.25
ICM7211MIPL	6.75
ICM7212AMIPL	6.12
ICM7213IPD	9.11
ICM7216AIJI	30.89
ICM7217AIPI	8.42
ICM7217BIJI	12.98
ICM7217IJI	15.26
ICM7218AIJI	9.30
ICM7218AIPI	8.68
ICM7218DIJI	10.95
ICM7218EIJL	14.76
ICM7224IPL	8.42
ICM7226AIJL	37.20
ICM7226BIPL	32.52
ICM7249IDM	POA
ICM7555IBA	0.99
ICM7555IPA	0.68
ICM7556IPD	1.16
IM6403IPL	12.92
L272	2.74
L272M	2.38
L293B	3.82
L293E	3.27
L297/1	6.98
L298N	7.80
L4805CV	3.40
L487	3.76
L4960	2.79
L702B	3.58
LA6358	POA
LA6510	4.88
LA6520	6.22
LC7132	POA
LC7522	6.97
LC7555	9.78
LD111ACJ	POA
LF13508D	13.65
LF311H	6.87
LF347N	1.34
LF351N	0.48
LF353N	0.61
LF355N	1.26
LF356N	1.33
LF357BN	2.98
LF357M	2.40
LF357N	1.33
LF398N	3.77
LF411CN	1.22
LF412CN	1.69
LF441CN	0.82
LF442CN	1.48
LF444CN	1.98
LH0002CN	13.04
LH0032CG	35.96
LM101AH	3.44
LM10CN	7.24
LM111H	5.21
LM13600N	1.89
LM13700N	1.58
LM1391N	1.98
LM139J	3.95
LM1458N	0.59
LM1496N	2.26
LM1801N	7.92
LM1881N	4.48
LM1889N	POA
LM1894N	POA
LM218H	POA
LM239N	3.90
LM2901N	0.86
LM2903N	0.86
LM2904N	0.86
LM2917N-14	6.10
LM2917N-8	3.64
LM294OCT15	POA
LM294OCT5	POA
LM2984CT	4.96
LM301AN	0.54
LM307N	0.96
LM308N	0.91
LM310N	2.56
LM311N	0.38
LM311N-14	2.15
LM312H	8.95
LM317AT	2.40
LM317T	0.76
LM317T-LT	2.64
LM318N	3.12
LM319N	2.68
LM320LZ-12	0.34
LM324AN	3.74
LM324J	1.71
LM324N	0.38
LM325N	6.09
LM3301N	2.60
LM334Z	1.71
LM335Z	1.62
LM336Z-2.5	1.48
LM336Z-5.0	1.48
LM337T	1.12
LM339AN	2.37
LM339N	0.34
LM340AT12	2.05
LM340T-5	0.70
LM340T12	0.70
LM340T15	0.70
LM343H	9.22
LM346N	4.12
LM348DP	0.64
LM348N	0.64
LM350T	4.77
LM351N	2.60
LM358N	0.36
LM359N	2.84
LM360H	7.72
LM361M	5.40
LM363H-100	16.50
LM369DN	3.82
LM369DRC	3.70
LM380N	1.98
LM381AN	7.88
LM385Z-1.2	1.98
LM385Z-2.5	1.98
LM386M1	1.65
LM386N1	1.28
LM386N3	1.80
LM386N4	2.60
LM387AN	5.20
LM388N1	4.25
LM389N	POA
LM3900N	1.02
LM3909N	2.12
LM3914N	3.25
LM393N	0.56
LM393P	0.96
LM394CN	4.80
LM3999Z	3.21
LM399H	6.68
LM4250J	11.82
LM555CN	0.68
LM565CN	2.48
LM710CH	1.71
LM723CH	1.63
LM723CN	0.72
LM733CN	2.65
LM741CJ-14	2.20
LM741CN	0.45
LM747CH	2.40
LM747CN	0.74
LM78GCP	1.80
LM79GCP	1.80
LM833N	1.31
LS285AB	2.40
LS288B	4.32
LS7210	POA
LT1006CNB	2.72
LT1010CT	4.58
LT1028CN8	7.98
LT1032CN	4.70
LT1070CT	10.98
LT1083CP	8.82
LT1086CT	3.81
LT1134CN	8.14
LTC1052	7.97
LTC1099CN	14.39
LTC485CN8	2.60
LTC490	4.40
M5218AL	3.20
M5220	6.21
M5238L	3.98
M5298P	6.22
M706B1	1.92
MAX134CPL	17.95
MAX1232CNG	POA
MAX1232CPA	2.42
MAX1259CPE	POA
MAX162ACNG	POA
MAX232ACPE	5.12
MAX232CPE	2.54
MAX232EWE	3.80
MAX232N	4.98
MAX280CPA	6.94
MAX452CPA	5.38
MAX627CPA	3.40
MAX660CPA	6.30
MAX690ACPA	4.66
MAX693CPE	6.68
MAX694CPA	5.70
MAX697CPE	6.59
MAX7219CNG	7.88
MAX8211CPA	2.28
MAX901BCPE	POA
MC1377P	4.93
MC1413P	0.74
MC14411P	14.25
MC14416L	POA
MC14495P	6.98
MC145406P	2.80
MC1455P	1.20
MC1455P1	1.40
MC1458P	0.60
MC1488L	2.40
MC1488P	0.42
MC1489AL	2.25
MC1489AN	0.80
MC1489L	2.20
MC1489P	0.38
MC1496N	1.76
MC1558L	3.32
MC1648P	12.40
MC1658P	12.78
MC1709CPI	1.20
MC1723CP	1.20
MC1741CP	0.45
MC3242AP	7.54
MC3301P	2.60
MC3302P	2.46
MC3340P	3.75
MC3357P	3.98
MC3403P	1.40
MC3446AP	6.75
MC3479P	7.92
MC3523U	5.80
MC4024P	12.78
MCT2	0.98
MCT61	1.18
MF10CCN	POA
ML924	4.90
MM5309N	5.76
MM53105N	4.98
MM80C95N	1.44
MP7570JD	POA
MUX24EQ	14.82
MUX24FP	14.82
MV500DP	2.86
MV601DP	4.96
MV8870DP	7.96
NE5020N	11.68
NE527N	4.63
NE532N	1.81
NE536H	4.90
NE5530N	3.82
NE5532AN	2.02
NE5532N	0.82
NE5534AN	1.28
NE555N	0.40
NE556/SMD	1.22
NE556N	1.18
NE558N	2.62
NE564N	3.75
NE565N	2.94
NE567N	0.91
NE568N	POA
NE570N	7.53
NE571N	4.96
NE589N	4.25
NE592/SMD	1.80
NE592N	2.00
NE592N14	2.00
NE602AN	2.98
NE604AN	8.98
NE605N	11.85
NE612AN	3.40
NJ8821DP	12.06
OP07CJ	3.60
OP07CN8	1.40
OP07CP8	1.40
OP07EP	3.10
OP11GP	8.68
OP177FP	3.71
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OP42FZ	9.03
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OP07CN	1.92
PCM63P-K	35.80
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RC4136N	0.80
RC4194N	2.15
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RC4558	0.91
RC4558P	0.91
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REF01HP	7.40
REF02CP	4.95
REF03GP	5.42
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SAA6002A	10.80
SAS560S	3.40
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SFC2301ADC	6.76
SFC2741DC	0.30
SG3524N	1.66
SI7660CJ	1.92
SL1452	7.85
SL2364C	3.97
SL3117B	POA
SL486DP	2.82
SL490DP	2.60
SL560CDP	2.62
SL6270CDP	2.97
SL6700CDP	POA
SN5281CN	POA
SN55451BJG	2.85
SOC12	0.22
SP1648DG	6.60
SP4534	POA
SP4740DP	4.46
SP8660DP	4.96
STK4141II	5.20
STK5151	POA
STK4171II	7.10
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STK4277SL	10.80
TA7215P	7.20
TA7256P	2.60
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TA7658P	1.20
TA78005AP	0.48
TA8200AH	7.82
TA8410K	2.80
TA8449P	6.31
TA8659AN	12.22
TAA861A	POA
TBA120S	0.80
TCM1520AP	POA
TCM1531P	POA
TCM1705AN	POA
TCM3105N	9.42
TCM5087N	3.44
TCM5089N	3.44
TDA1023	2.30
TDA1083	3.40
TDA1085A	3.80
TDA1085C	3.80
TDA1151	1.88
TDA1170S	3.54
TDA1515A	4.98
TDA1521A	4.98
TDA1576	4.98
TDA1578A	4.81
TDA2086/A	POA
TDA2595	4.41
TDA3048N	1.85
TDA3505	POA
TDA3810	POA
TDA440	POA
TDA4510	3.38
TDA4563	4.98
TDA4660	6.60
TDA6579T	POA
TDA7010T	POA
TDA7052	2.52
TDA8702	6.22
TEA1045	POA
TEA1060	4.20
TEA5620	POA
TIPC2801KV	8.79
TL026CP	1.84
TL062CN	1.26
TL062CP	1.30
TL064CD	0.98
TL064CN	0.84
TL064ID/SMD	2.10
TL071ACP	1.57
TL071CP	0.78
TL072ACP	1.64
TL072CN	0.72
TL072CP	1.30
TL074ACN	2.40
TL074CN	0.97
TL081CP	0.74
TL082CN	0.81
TL084CN	0.84
TLC27L2CD	1.98
TL497ACN	3.95
TL507CP	5.98
TL7702ACP	1.22
TL7705ACP	1.22
TL7705CP	1.22
TL7709ACP	2.04
TL7770-SC	3.82
TL783CKC	7.53
TLC1541IN	15.63
TLC2201CP	5.50
TLC2274CN	POA
TLC251CP	4.28
TLC2652CP	5.98
TLC2654CP	5.98
TLC271CP	1.20
TLC272CP	2.18
TLC272CD	2.29
TLC274CN	3.09
TLC339CN	2.58
TLC372CP	1.95
TLC551CP	4.62
TLC555CP	1.44
TLC556CN	2.53
TLC7524CN	5.98
TLE2061CP	POA
TLE2062CP	POA
TLE2064CN	POA
TLE2161CP	POA
TMS3477NL	6.68
TPIC2406NE	7.14
TPIC2802KV	9.42
TPIC6259N	3.28
TPIC6273N	3.28
TPIC6595N	3.28
TSC426CPA	POA
TSC500CPE	POA
TSC7106CPL	6.81
TSC7116CPL	7.68
TSC7126CPL	8.28
TSC7660CPA	1.40
U1096B	4.92
U2066B	2.64
U2400B	5.50
UA2240CN	2.79
UA2240PC	2.79
UA709CP	0.85
UA709PC	0.85
UA715HC	4.50
UA723CP	0.70
UA733CJ	2.98
UA741MP	0.60
UA741TC	0.28
UA748CP	0.98
UA77000UIC	POA
UA798TC	3.80
UCN5800A	2.83
UCN5801A	3.96
UDN2981A	3.15
UDN2982A	3.02
UDN6118A	2.13
UGN3501M	POA
ULN2001AN	0.58
ULN2002A	0.58
ULN2003AN	0.58
ULN2004AN	0.58
ULN2024A	POA
ULN2032A	POA
ULN2801AN	0.84
ULN2803AN	0.84
UM5100	POA
UM5101	4.52
XR2211CP	POA
XTR110KP	11.84
Y1112/TI	4.60
YM3623B	15.48
ZN1034E	2.66
ZN414Z	1.20
ZN415E	POA
ZN416E	2.32
ZN423	2.20
ZN425E8	4.95
ZN426E8	5.35
ZN427E8	11.35
ZN428E8	6.40
ZN429E8	1.98
ZN432E	21.49
ZN448E	7.95
ZN449E	6.75
ZNA134E	16.72
ZNA134H	12.73
ZNA234E	POA

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75107	1.68
75107A	1.68
75108	1.42
75108A	1.84
75108B	2.08
75109A	2.46
75110A	2.43
75113	2.02
75114	2.26
75115	2.26
75116	5.74
75121	2.59
75122	POA
75136	POA
75138	5.74
75140	3.35
75150	1.39
75150M	1.39
75152	6.36
75154	1.33
75154M	1.39
75155	3.06
75157	4.40
75159	5.45
75160A	6.15
75161A	6.15
75162A	6.15
75172	2.46
75173	2.46
75174	2.46
75174NG	4.21
75175	2.80
75176A	2.69
75176B	1.86
75176BT	2.19
75177	2.60
75178	4.14
75182	2.93
75183	2.93
75188	0.98
75189	0.98
75189A	0.98
75361	3.74
75365	3.50
75437A	3.26
75450B	0.66
75451	0.66
75451B	0.96
75452	0.66
75452B	0.96
75453	0.66
75453B	0.96
75454	0.66
75454B	0.98
75462	1.31
75463	1.10
75468	3.15
75469	POA
75470	POA
75471	3.35
75472	3.35
75473	3.35
75474	2.25
75477	2.10
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75ALS193J	4.72
75C1154	4.06
75C1406	3.51
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75C188	2.32
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75C189AD	2.32
75LBC176	4.14

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40406	1.60
40673	2.40
BC107A/B	0.17
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BC109B/C	0.18
BC140-16	0.48
BC146/01	0.58
BC149	0.40
BC157	0.34
BC158	0.34
BC169C	0.14
BC179	0.24
BC182	0.08
BC182A	0.08
BC182B	0.08
BC182L	0.08
BC182LB	0.08
BC183	0.08
BC183C	0.08
BC183L	0.08
BC184	0.08
BC184B	0.08
BC184L	0.08
BC184LC	0.08
BC212-18	0.08
BC212A	0.08
BC212B	0.08
BC212L	0.08
BC212LB	0.08
BC213	0.08
BC213L	0.08
BC214	0.08
BC214L	0.11
BC237	0.08
BC239	0.12
BC307	0.08
BC327	0.08
BC328	0.08
BC337	0.08
BC337-25	0.08
BC489	0.24
BC490	0.30
BC516	0.22
BC517	0.20
BC546	0.05
BC546A	0.05
BC546B	0.05
BC547	0.08
BC547A	0.08
BC547B	0.08
BC547C	0.08
BC548	0.08
BC548B	0.08
BC549	0.08
BC549B	0.08
BC550	0.08
BC550B	0.08
BC550C	0.08
BC556	0.08
BC556A	0.08
BC556B	0.08
BC557	0.08
BC557B	0.08
BC558	0.08
BC558A	0.08
BC558B	0.08
BC559A	0.08
BC559B	0.08
BC560A	0.08
BC560C	0.08
BC184C	0.08
BCY71	0.22
BD131	0.88
BD135	0.44
BD241A	0.98
BD242C	0.52
BD243	0.50
BD516	0.78
BD675	0.52
BD676	0.52
BD679	0.54
BD680	0.56
BD743C	1.90
BDT85	1.12
BDX67B	2.78
BDY96	3.60
BF195-C	0.08
BF199	0.22
BF200	0.16
BF256B	0.38
BF256C	0.38
BF259	0.40
BF324	0.28
BF421	0.12
BF450	0.20
BF451	0.22
BF494	0.16
BF759	0.26
BF961	0.66
BF981	0.90
BF982	0.88
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BFR91-5GHz	0.90
BFR91A-6GHz	1.20
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BFX48	0.49
BFX85	0.59
BFX88	0.30
BFX89	1.59
BFY50	0.34
BFY52	0.34
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BS107	0.28
BS170	0.38
BS250	0.52
BSR60	0.48
BSX20	0.38
BSX21	0.48
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BUZ11A	1.62
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IRFZ14	1.14
IRFZ20	1.77
J113	0.39
J175	0.68
J270	0.92
JA101	0.48
MBD501	1.10
MJE13070	1.10
MJE340	0.68
MJE350	1.10
MJE520	0.80
MPS3638	0.18
MPSA06	0.12
MPSA13	0.12
MPSA63	0.32
MPSA92	0.24
MPSU05	2.21
MTP8P08	2.80
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PN3643	0.18
TIC106M	0.78
TICP206D	0.61
TICV106D	0.24
TIP115	0.55
TIP121	0.68
TIP145	1.37
TIP2955	0.88
TIP30	0.48
TIP3055	0.88
TIP31A	0.38
TIP32A	0.40
TIP47	0.80
V275LA10	0.92
VN0104N3	0.92
VN66AFD	1.40
VN90AB	2.96
VP0104-N3	0.92
VP0104N2	0.98
VP0104N3	0.92
ZTX212	0.18
ZTX237	0.26
ZTX300	0.18
ZTX313L	0.28
ZTX320	0.38
ZTX510	0.18
ZTX550	0.24
ZTX551	0.36

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2N2222	0.28
2N2222A	0.22
2N2369	0.24
2N2369A	0.24
2N2484	0.32
2N2894	0.78
2N2905	0.32
2N2905A	0.32
2N2907	0.30
2N2907A	0.30
2N2923	0.30
2N2243	0.78
2N3053	0.34
2N3055	0.98
2N3441	1.20
2N3553	0.98
2N3684	1.68
2N3702	0.10
2N3704	0.10
2N3706	0.10
2N3725	0.78
2N3789	2.16
2N3819	0.54
2N3866	1.24
2N3904	0.11
2N3905	0.12
2N3906	0.10
2N3958	2.12
2N4037	0.48
2N405	2.30
2N4062	0.32
2N4091	0.78
2N4123	0.10
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2N5485	0.48
2N5876	1.32
2N6034	0.72
2N6037	0.72
2N6050	3.12
2N6051	3.49
2N6054	2.20
2N6056	1.94
2N6057	2.24
2N6058	2.68
2N6109	0.78
2N6125	2.88
2N6388	0.98
2N6517	0.34
2N6519	0.34
2N6668	1.40
2N696	0.26
2N706A	0.48
2SK129A	5.24
2SK246Y	0.30
3SK45	1.85
3SK88	0.84

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2SA1048Y	0.14
2SA1096R	0.96
2SA1100	0.60
2SA1102	2.10
2SA1104	2.40
2SA1111	0.88
2SA1115	0.20
2SA1145	0.45
2SA1263N	1.80
2SA1264N	2.60
2SA1265N	2.60
2SA1283	0.28
2SA1295	7.32
2SA1302	3.74
2SA1399	0.58
2SA1482	0.78
2SA1515	0.78
2SA1516	3.24
2SA733	0.30
2SA854S	0.52
2SA933	0.24
2SA933S	0.39
2SA965	0.60
2SA968	1.10
2SA970	0.32
2SB1052	1.20
2SB1185	1.52
2SB1238	0.82
2SB750A	1.60
2SB834	1.04
2SB949	1.48
2SB950	1.40
2SC1079	5.80
2SC1115	4.00
2SC1129	0.48
2SC1213	0.40
2SC1279	1.10
2SC1318	0.60
2SC1740S	0.40
2SC1741S	0.32
2SC1775	0.28
2SC1845	0.28
2SC2009	0.44
2SC2180N	8.96
2SC2235	0.40
2SC2238/O	0.76
2SC2238B	0.76
2SC2240	0.24
2SC2275	0.64
2SC2275A	0.88
2SC2278	1.18
2SC2362	0.34
2SC2389	0.36
2SC2497	1.20
2SC2577	1.84
2SC2579	3.20
2SC2591	1.38
2SC2603	0.32
2SC2705	0.44
2SC2928	4.82
2SC3180N	2.38
2SC3181N	2.60
2SC3182N	2.64
2SC3243	0.36
2SC3281	2.72
2SC3284	5.00
2SC3377	0.24
2SC3581	0.56
2SC369	0.44
2SC373	0.44
2SC3907	4.20
2SC458	0.15
2SC485	1.88
2SC486	1.88
2SC497	1.64
2SC538A	1.98
2SC627	0.68
2SC815	0.68
2SC826	0.82
2SC853	0.82
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FOCUS ON: CD ROM STANDARDS AND APPLICATIONS

Since the introduction of the audio compact disc (CD) in 1982, this digital information carrier has been the nucleus of many developments. Today, the CD is not only used for music, but also for computer data and video. This article discusses the various CD standards that have evolved over the years. These are world standards which have been defined in the Red Book, Yellow Book, Green Book, Orange Book and White Book.

By our editorial staff

THE Compact Disc was born in Eindhoven, The Netherlands, at the Philips Research Laboratories. There, the concept of optical registration of digital data was developed. In 1980, when Philips N.V. and Sony agreed to promote the CD as a carrier of digital audio, it was difficult to foresee the overwhelming effect the silver disc would have on the music industry. In five years' time, some 30 million CD players were operational, and 450 million CDs sold. The gramophone, Edison's invention, and the most important sound medium for 80-odd years, was dead and buried at 'record' speed.

Since then, there's no stopping the CD. The shining silver disc is used for an increasing number of applications. The White Book, for instance, published in 1994 by Philips and JVC, gives details of the video CD, a CD variant which looks poised to open the attack on the pre-recorded video tape. In the course of this year, both the computer industry and manufacturers of consumer electronics will introduce various systems which support digital video based on the video CD. This puts the video CD in a position to become accepted just as rapidly as the CD-DA (audio CD).

Today there are so many CD standards that it is difficult to see the wood for the trees. These standards are, therefore, briefly discussed below.

Red Book, CD-DA

The standard for digital audio, **CD-DA**, may be found in the Red Book, which contains all technical specifications concerning registration and error correction pertaining to the CD. The Red Book has become the basis for later CD standards and developments, which were once beyond the specs laid down in the Red Book because of high technical demands on the CD.

The information on a CD consists of a spiral-shaped string of holes pressed into a transparent polycarbonate layer. Next, a reflecting aluminium layer is applied which is covered with a transparent protection layer. The space between two holes is called an island. A laser beam scans the spiral from centre of the disc. Because the recording device in the laser drive unit is capable of detecting whether the light is reflected by a hole or an island, it is possible to recover the information pressed on the CD. Variations in the intensity of the reflected light are used to focus the laser via a complex servo system.

The spiral on the CD is divided into three sections: the lead-in, the program (data) and the lead-out. To make the best possible use of the space on the CD, the spiral is scanned at a constant speed. The CD's rotation speed is therefore dependent on the position of the laser. In the program section, the rotation speed can vary between 197 and 539 revolutions per minute. Because a mechanical speed control alone does not enable a constant data flow, the player has a buffer memory which has to be half filled all the time. If less than 50% of the available space is used, the drive speed is increased. If more than 50% is used, the speed is lowered accordingly. The data read by the laser is clocked out of the buffer with the aid of a quartz-controlled oscillator. The buffer/clock system guarantees a perfectly stable datastream into the DAC which follows the CD drive unit.

All data on an audio CD represents sound signals which have been sampled at a frequency of 44.1 KHz. Each sound channel is linearly digitized at a resolution of 16 bits. The result is a datastream with a speed of 1.4112 Mbit per second.

Yellow Book, CD-ROM

The next standard to appear on the market was defined in the Yellow Book, again produced jointly by Philips and Sony. Once the enormous storage capacity of CDs was fully recognized, the idea of a **CD-ROM** was born. The CD-ROM is marketed as the replacement for magnetic media such as floppy disks and hard disks. It has a number of advantages and disadvantages. The advantages include low cost, large storage capacity, non-volatile character, and reliability. On the down side, a CD-ROM is a read-only medium.

To maintain compatibility with the

CD-DA, the CD-ROM also contains one long spiral. This is in stark contrast with the long-established system of parallel tracks on magnetic media. Because the CD-ROM is also read at constant speed, it has a fairly large random read access time. Any time a file has to be read, the motor speed has to be adjusted until the right reading speed is achieved, and that takes time. Furthermore, the data transfer speed offered by the CD-ROM is relatively low at about 150 KByte per second. Fortunately, double, triple and quadruple speed CD-ROM drives have arrived, and we may see further improvements in the near future.

The information in the Yellow Book does not go much further than a description of the idea to store computer information in the program section. Further, it indicates the types of error correction methods which can be added to the system. The Yellow Book contains neither descriptions of the structure of files and directories as used with computers, nor information on how audio-visual (multimedia) information is to be stored. Consequently, the ISO-9660 and CD-ROM-XA standards were introduced later.

The ISO-9660 standard was initially developed by the High Sierra Group, and taken over by the ISO in 1988. It describes the file structure used with IBM-compatible PCs, and has become the basis for later standards. The UNIX platform uses the RRIP (Rock Ridge Interchange Protocol), while Apple Macintosh users have the HFS (Hierarchical File System) for their CD-ROMs.

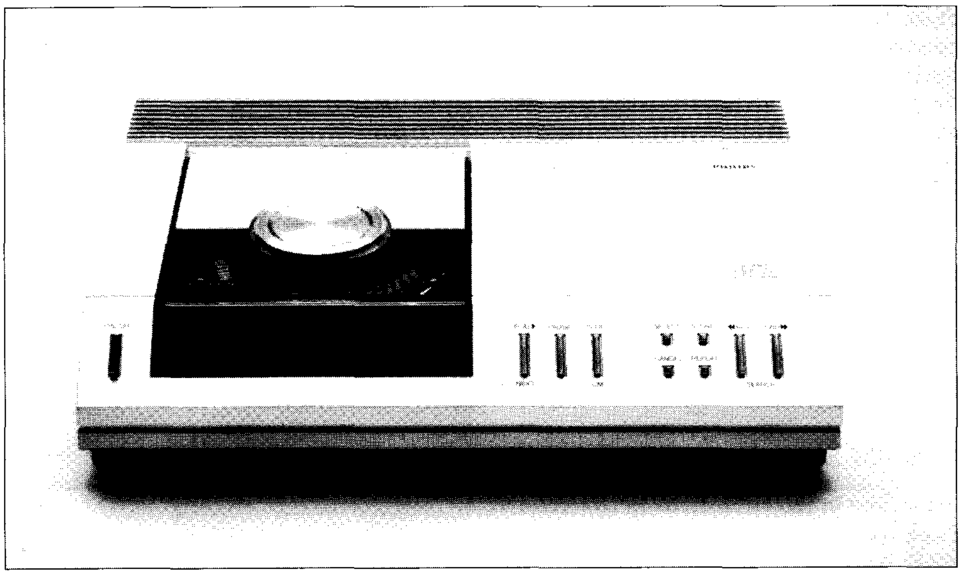


Fig. 1. The CD-DA (audio CD) was the first CD for a big audience. This Philips CD player was a market hit during the early nineteen-eighties.

Green Book, CD-i

In 1986, less than a year after the introduction of the CD-ROM, the **CD Interactive** (CD-i) was announced as a multi-media system for the consumer market. The complete system description may be found in the Green Book. Multimedia systems which process audio-visual information are an interesting application area of the CD-ROM. As already mentioned in the description of the CD-DA, audio information is recorded at a speed of 1.4112 MBit/s. Because video information is far more complex than audio information, the amount of data required for digital video will be even greater. Both with audio and video, there is an interaction between the necessary datastream and the quality of the encoded signal. The CD-i specification describes lots of possibilities for the recording of multi-media information such as sound, still-video, animations and video. Moreover, the information is stored in an interleaved pattern, which means that, for instance, audio and video are interwoven in blocks. That allows the CD-i player to read several types of information simultaneously.

The essential difference between CD-i and CD-ROM is that the specifications of the former include a complete description of the hardware which is necessary to be able to use the CD-i software. The Green Book also provides information on the structure of the data pressed on a CD-i disc. A marked difference with the Yellow Book, which has nothing on data storage formats.

Chapter 9 of the Green Book describes how MPEG1 full-screen video encoded according to ISO 11172 may be added to CD-i information. This system is called 'digital video on CD-i' and has been added to the CD-i system as an option.

CD-ROM XA

CD-ROM XA (eXtended Architecture) denotes an extension of the CD-ROM standard drawn up to make the medium better suited to multi-media applications. Broadly speaking, the XA standard enables a number of CD-i compatible audio and video formats to be used with CD-ROM also. Furthermore, it intro-

Fig. 2. The CD-ROM drive is on the way to becoming just another standard peripheral in computer land.

duces the possibility of different start directories, which enables you to run a CD under different operating systems. Finally, the CD-ROM-XA standard, like the CD-i, is structurally compatible with the ISO-9660 standard. That makes the CD-ROM-XA suitable for many different computer systems. This type of disc is, however, unsuitable for CD-i players because they often lack the appropriate programs. Despite the fact that the XA standard has been with us for some time, little software has become available so far which utilizes this standard.

Table 1.

Standard	standard book	system holder	introduction
CD-DA	Red Book	Philips, Sony	1982
CD-ROM	Yellow Book	Philips, Sony	1985
CD-i	Green Book	Philips, Sony	1987
CD-ROM XA		Philips, Sony	1989
CD-ROM MO/CD-WO	Orange Book	Philips, Sony	1990
CD-Bridge		Philips, Sony	1991
Photo CD		Kodak, Philips	1992
Video CD	White Book	JVC, Philips	1994

Sector structure

According to the definitions in the Yellow Book, sectors on a CD have a length of 2,352 bytes, and are subdivided into a number of fields to make them accessible to computers. The start of a sector is indicated by a synchronization pattern of 12 bytes. This is followed by a 4-byte header which contains its absolute address in minutes, seconds and sectors, as well as a mode byte. That leaves 2,336 bytes available for data storage in each sector.

All sectors in one track use the same mode. Sectors exist in three different modes. In Mode-0 sectors, all remaining 2,336 bytes are empty, i.e., zero. Mode-1 sectors contain 2,048 bytes of user data, protected by an EDC (error-detecting code) and an ECC (error-correcting code). This error protection is additional to the protection already used for CDs. Although the standard error correction for CDs is application independent, it is not powerful enough for computer applications. This is because small data errors are unacceptable in computer systems, although they may go by unnoticed in audio systems.

Fig. 3. A CD-i player is compatible with many different CD formats.

In Mode-2, which is the format used for normal CD-ROMs that do not require extra error correction (for instance, digitized audio/video), the remaining 2,336 bytes are available to hold data. The structure of Mode-2 sectors is further detailed in the Green Book to ensure compatibility with the ISO-9660 standard. The extension with Mode-2 is used with CD-i and CD-ROM-XA. It involves the storage of data in sectors by assigning a sub-header to each sector. This sub-header contains a file and channel number coding information for details on the type of data contained in the sector, as well as a sub-mode byte. The file number is used to distinguish between sectors of different, interleaved, files. The channel number is used to support the different channels a file may be composed of. The sub-mode byte contains the end-of-file (EOF) and end-of-record (EOR) bits, an interrupt trigger bit to enable synchronization, and a real-time bit which indicates that the file is used in real time mode.

Finally, three bits follow which indicate the type of data (video, audio, computer, etc.) in the sector. This extension has two options: mode-2/form-1 and mode-2/form-2, where the form bit indicates whether or not the additional error correction used in Mode-1 sectors is employed. Mode-2/form-1 sectors do have this extra error correction (EDC and ECC), while mode-2/form-2 sectors have an EDC block only. The absence of extra error correction is justified if the CD contains audio or video information. With these file types, the absence of the real-time bits (even occasionally) is much more important than small data errors. Because the extra error correction is not used, 280 bytes are available for data storage. With a real-time file stored in a mode-2/form-1 sector, the error detection and correction operations have to be performed in real time also, which makes high demands on the relevant hardware.

The eight space bytes in a Mode-1 sector are usually zero, and used for the header in Mode-2. Consequently, the locations for the data and the EDC fields are moved by eight bytes. A mode-2/form-2 sector is closed off by a 4-byte EDC field only, which may contain parity bits which serve as quality indicators in the CD production process. These bytes may also be made zero. If they are used, it is recommended to employ the same EDC as with mode-2/form-1 sectors.

Orange Book, CD-MO and CD-WO

The Compact Disc Magneto-Optical (**CD-MO**) and Compact Disc Write Once (**CD-WO**) are specified in the Orange Book. This extension has given the CD an even wider application area, because it specifies how CDs may be produced in small quantities.

The CD-MO enables the information on a CD to be re-written several times. By contrast, the CD-WO system allows data to be written once only. The CD-MO has a magneto-optical layer in which the information is stored in a completely different manner than with a normal CD. The read section of the laser recognizes a CD-MO disc from a change in the polarization direction of the laser light. A special drive unit is required for the reading and writing of this type of CD.

A CD-WO, *a.k.a.* CD Recordable (CD-R) has three status levels: it is either blank, partly written on, or completely written on. Like the CD-MO, the CD-WO contains a special pre-recorded track with information required for tracking and timing. The CD-WO contains a light absorbing layer of which the reflection characteristics are modified with a special laser during recording. A CD-WO enables CD's to be 'burnt' which are compatible with the Red, Yellow and Green Book. These discs can be played on any conventional CD player or CD-ROM drive.

The CD-WO standard also supports the use of multiple partitions on a single CD ('multi-session'). Each of these partitions has its own lead-in, program and lead-out sections, and is compatible with the standards in the Red, Green or Yellow Book. Such a multi-session CD can only be read by a special multi-session drive. An ordinary CD-ROM drive can only read the data in the first session.

CD-Bridge

The **CD-Bridge** standard was developed to bridge the CD-i and CD-ROM standards. It is a very open standard with plenty of room for the implementation of the various system specifications. A CD-Bridge disc is a CD-ROM-XA disc which also contains a CD-i program. Consequently, this type of disc may be used in a computer as well as in a CD-ROM-XA drive. The popular photo-CD and Video-CD are examples of CD-Bridge discs.

Photo-CD

The **Photo-CD** is a CD-Bridge disc of which the standard was designed by Philips and Kodak. This type of CD is intended for the storage of photographs which have been digitized at a very high solution, and so allows you to view photographs on your TV or computer screen. The relevant file may be processed further on the PC, or printed on paper.

A Photo-CD may be an ordinary CD, produced with conventional means, or a CD-WO. The latter format allows photos to be added to the CD during further sessions. Obviously, pre-recorded Photo-CDs have one session only, and can be read by all types of CD-ROM.

The standard version of the Photo-CD is based on 35-mm photographic negatives which are digitized at a resolution of 3782 x 2048 pixels. The file recorded on the CD consists of five sub-files: Base/16, Base/4, Base, 4xBase and 16xBase. Thanks to data compression techniques, an ordinary CD can hold more than 100 digitized 35-mm photographs. These days it is also possible to put larger film formats onto a Photo-CD. This is particularly interesting for professional users of photographic material.

Table 2.
Compatibility between disk format and player.

Disk	player/system					
	CD-DA	CD-ROM	CD-ROM-XA	CD-i	Photo CD	Video CD
CD-DA	x	x	x	x	x	x
CD-ROM	-	x	x	-	-	-
CD-ROM XA	-	-	x	-	-	-
CD-i	-	-	-	x	-	-
CD-Bridge	-	-	x	x	-	-
Photo CD	-	-	x	x	x	-
Video CD	-	-	x	x	-	x

x = compatible
- = not compatible

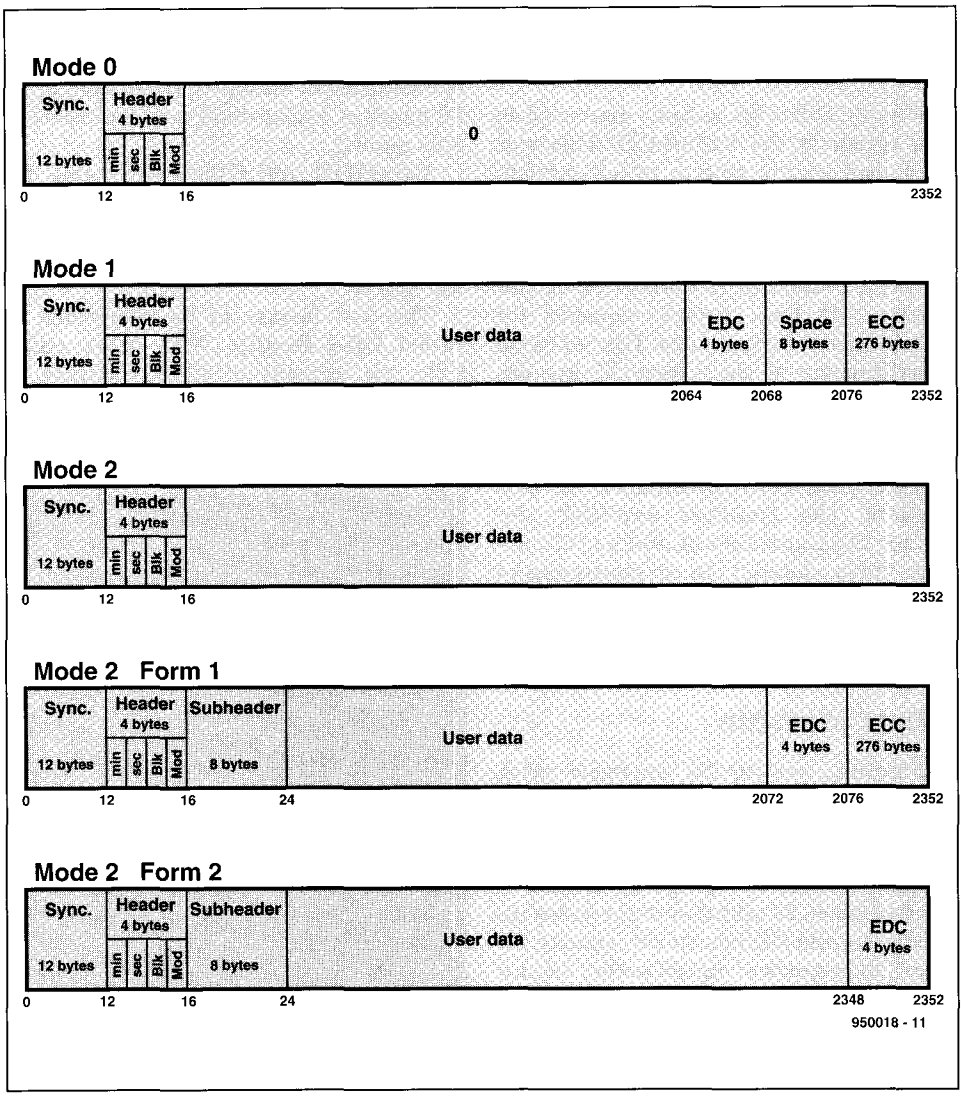


Fig. 4. The data structure on a CD-ROM is strongly dependent on the application. This drawing shows the sector structure of the CD-ROM, CD-ROM-XA and Cd-i formats.

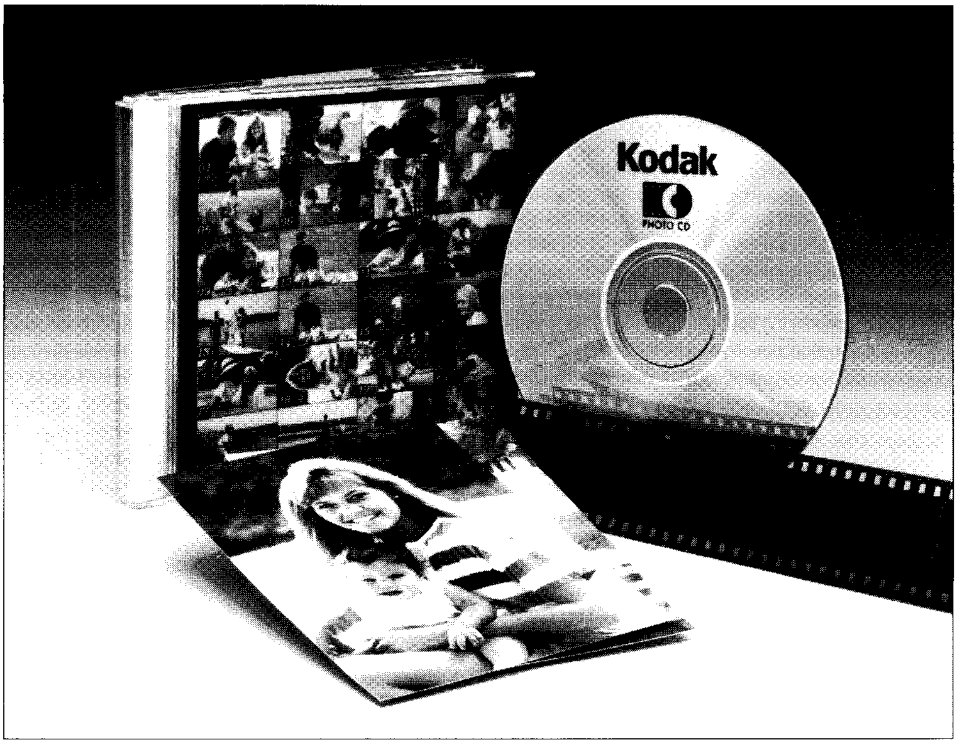


Fig. 5. The Photo-CD format was designed Kodak and Philips. It allows over 100 35-mm negatives to be stored on a single CD without loss of quality.

White Book, Video-CD

The last CD-Bridge variant discussed in this article is the **Video-CD**. This was developed for the storage of full-motion, full-screen, video, as already described in Chapter 9 of the Green Book (CD-i). The pictures on the CD are encoded to the MPEG-1 standard. A normal 12-cm diameter CD has storage capacity for 74 minutes of digital video. The technical specifications of the Video-CD are described in the White Book. Initially, this version was also known as the Karaoke-CD standard.

To further the acceptance of this medium, the standard explicitly describes the possibility of adding full-motion video decoder to a conventional audio CD player. As a matter of course, that is only possible if the player is modified accordingly.

Other formats

CD-Video, not to be confused with Video-CD, is a CD format which has been in use for some time to record five to six minutes of analogue video on a CD. This format is described as an extension in the Red Book. In addition to the video information, the CD has spare capacity for about 20 minutes of digital audio. After a few false starts, this format soon went into oblivion. Today, it is hardly produced any more.

The CD Background Music (**CD-BGM**) format was developed for background music ('Muzak') systems, and is based on technologies derived from the CD-i standard. By virtue of the ADPCM encoding used, a single CD can hold up to 20 hours of background music at reasonable quality.

CD+MIDI and **CD+G** were also developed on the basis of the audio CD. These formats enable graphics and MIDI data to be put on a CD, together with digital audio.

The last format to be mentioned is called **CD-i Ready**. With these audio CDs, an amount of CD-i software is stored in the background. When the CD is played on an audio CD player, this extra functionality is not noticed because the disc behaves just like any other music CD. The CD-i software comes to life once the disc is inserted in a CD-I player. Additional functions which are then available include song texts, photographs, discographies, etc. To make sure that the CD-i information does not interfere with the music reproduction, the CD-i player first reads its own information, and stores it in a buffer. Next, the associated audio track is played.

Finale

A plethora of CD standards is currently in use, and the overall situation is complex enough to look pretty bewildering at first glance. As a general tip, formulate your requirements before you go out and purchase a CD player or a CD-ROM drive. Use the information in **Table 2** to check for yourself which standards are actually required for your particular applications, and then select a player which supports at least those standards.

(950018)

Source:
Compact Disc Standards, an Introductory Overview, by Jan Korst and Verus Pronk, Philips Research Laboratory, Eindhoven, The Netherlands.

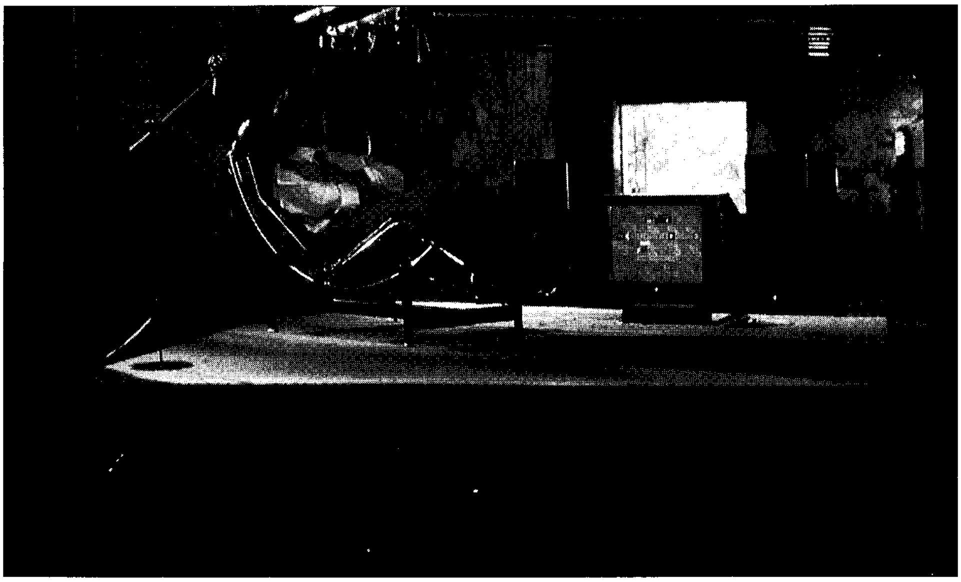
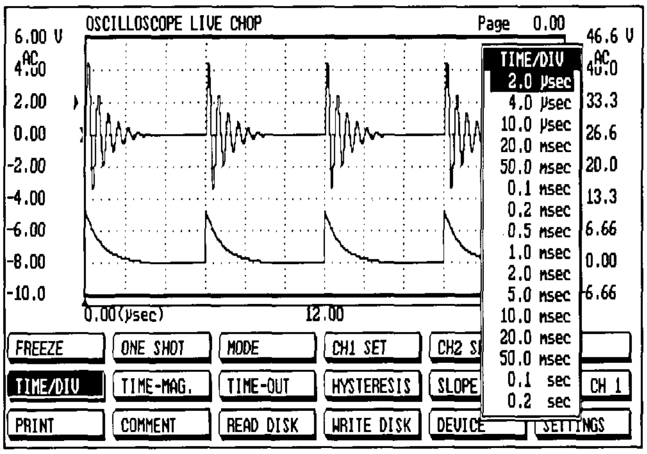


Fig. 6. The Video-CD is expected to take a large market share away from the pre-recorded video tape. Computer users, too, can use this CD format to load and display digitized photos with the aid of an MPEG insertion card.

DATA ACQUISITION WITH THE PC



TiePie engineering manufactures a complete range of computer-controlled measuring instruments. Connecting these units to a PC (MS DOS 3.0 or higher) results in a number of comprehensive test instruments:

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- spectrum analyzer;
- frequency meter;
- transient recorder.

All measured data can be stored on disk or run off for documentation. Because of the many trigger possibilities, a variety of signals can be measured, while the powerful software enables a multitude of measurements to be carried out in a straightforward manner. Application areas include: service; medical research; automatic test systems; research and development; and education.

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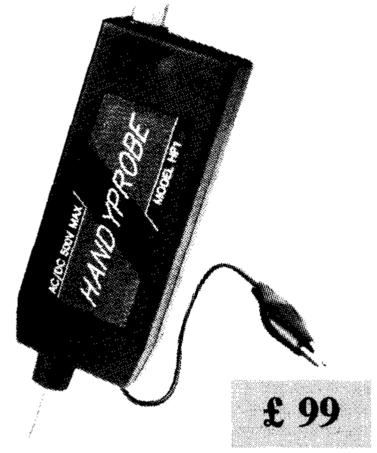
Connect the HANDYPROBE to the parallel printer port of the PC and start the software. Measuring can be carried out at once. The HANDYPROBE does not need an external power supply. Some technical parameters: 0.5-400 V software select input range; one input channel; 8 bits resolution (overall accuracy 2%); A complete software program consisting of a digital storage oscilloscope, spectrum analyzer, voltmeter and a *transient recorder* is provided. The HANDYPROBE is eminently suitable for servicing and educational purposes.



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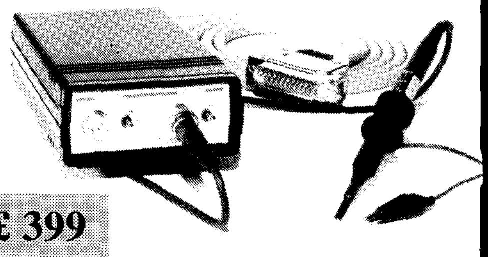
BEST PERFORMANCE: HANDYSCOPE

The HANDYSCOPE is connected to the parallel printer port. This makes it possible to carry out measurements with a laptop or notebook PC. Because of its high resolution (12 bits), the HANDYSCOPE is a very accurate instrument. The measuring rate is 100,000 samples/sec. Either of the two channels can be set independently over a range of 0.5-20 V (with a 1:10 probe up to 200 V). The advanced software enables many measurements to be carried out. Two probes (switchable 1:1-1:10) are provided. The HANDYSCOPE is constructed as a small table model with two BNC connectors. The length of the cable linking the PC and the HANDYSCOPE is 1.8 m, which can be extended to 3.8 m.



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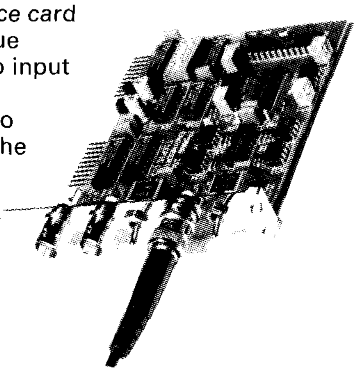
MULTIFUNCTIONAL: TP5008

The TP5008 is an interface card that provides an analogue output in addition to two input channels. This output in combination with the two inputs may be used for the setting up of a complete control loop. The output may also be used as a function generator. The TP5008 has a resolution of 8 bits and a sampling rate of 200,000 samples/sec (200 kHz). The input range may be set to 0.5-20 V full-scale deflection. The output range covers 1.25-2.5 V. The TP5008 is fitted with BNC connectors and is delivered complete with a user manual and software. Separately available are 1:1-1:10 probes and 1:100 oscilloscope probes.



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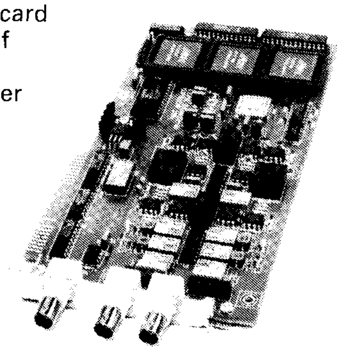
VERY HIGH SPEED: TP208

The TP208 is an interface card with a measuring speed of 2×20 Megasamples/sec (8 bits). Phenomena shorter than one millionth of a second can still be measured well. The completely digitized triggering ensures very stable triggering with many trigger possibilities. The TP208 has an input range of 5 mV/div to 20 V/div in 12 steps and an auto calibration function. Since both channels may be sampled simultaneously, phase differences can be measured very accurately. Even single phenomena can be measured since each channel has a 32 KByte memory. Comprehensive software is provided.



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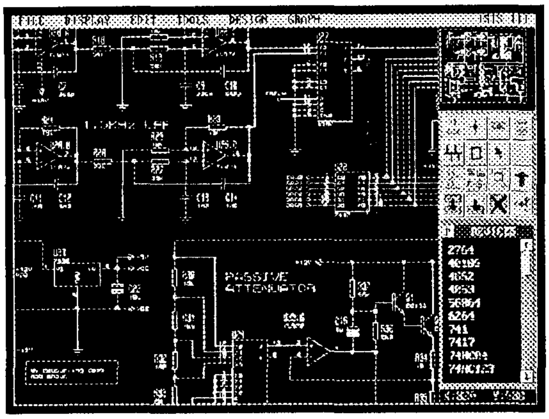

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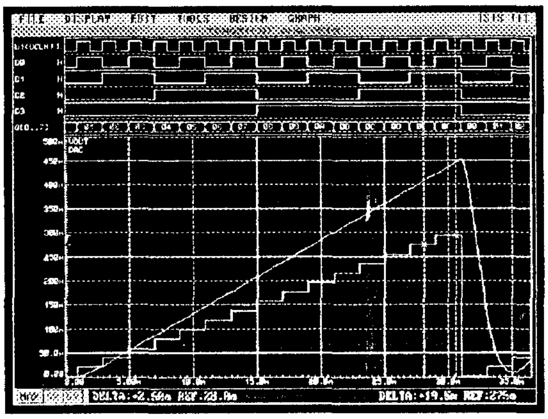

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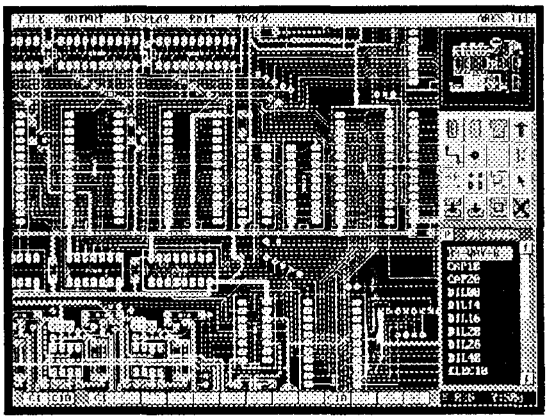

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DIGITAL SIGNAL PROCESSORS

By L. Lemmens

This article is intended as a brief introduction to digital signal processors (DSPs) and what makes them different from traditional processors and microcontrollers. The description is based on the ADSP-2100 family from Analog Devices, which includes the ADSP-2105 used in the DSP function generator described elsewhere in this issue.

The fundamental theory of DSP is Shannon's Sampling Theorem (1949) which states how often a time-varying signal is to be monitored if it is to be reconstructed exactly from its digital samples. It can be simply stated as follows:

> In order to recover the signal function *f*(*t*) exactly, it is necessary to sample *f*(*t*) at a rate greater than twice its highest frequency component.

For instance, an audio signal whose highest frequency is 18 kHz should be sampled at 36 kHz to preserve and recover its waveform exactly.

Sampling a signal at a rate below its highest frequency component results in a phenomenon called *aliasing*. This results in a frequency erroneously taking on the identity of an entirely different frequency when recovered.

Multi-functionality

In spite of their name, digital signal processors are intended to process analogue signals. However, since they are digital devices, the signal must first be passed through a analogue-to-digital converter. After the signal has been processed, a digital-to-analogue converter (DAC) is needed in many applications. The two conversions are not normally carried outby the DSP but by external devices.

When analogue signals are digitized, their waveform is translated into a digital number at set intervals. The consequent series of numbers is passed through a digital filter (or filters) and their frequency spectrum is then determined by a Discrete Fourier Transform (DFT) or a Fast Fourier Transform (FFT). The power spectrum determination lies at the heart of a range of DSP operations, from speech recognition to the analysis of seismic data.

The mathematics underlying the sampling theory and the Fourier transform are too complex to be discussed in an article of this nature, but can be found in many textbooks. However, in practice, the processes come down to the computation of a series of products. Such a computation consists of (a) fetching two numbers from the memory; (b) multiplying the numbers; (c) accumulating the result; (d) storing the result in memory.

Apart from the fact that standard processors do not possess a multiplication facility, they would need many cycles to perform one such operation. Digital signal processors can perform several actions in parallel during one cycle and can even do so in real time.

A typical DSP in the ADSP-2100 family operates at 12.5 MHz and executes an instruction in a single 80 ns cycle. Since all instructions are carried out in a single cycle, MIPS (Million Instructions Per Second)= MHz. Its flexible architecture and comprehensive instruction set make possible a number of parallel operations. In one cycle, the ADSP-2100 can

- generate the next program address;
- fetch the next instruction;
- performone or two data moves;
- updata one or two data address pointers;
- perform a computational operation.

Architecture

Figure 1 is an overall block diagram of the ADSP-2105. The processor contains three independent computational units: the arithmetic logic unit (ALU), the multiplier/accumulator (MAC) and the Shifter. These units process 16-bit data directly and have provisions to support multiprecision computations.

The ALU performs a standard set of arithmetic and logic operations; division primitives are also supported.

The MAC performs single-cycle multiplication, multiplication/addition and multiplication/subtraction operations.

The Shifter performs logical and arithmetic shifts, normalization, denormalization and derive exponent operations. The Shifter can be used to implement efficiently any degree of numeric formal control, up to and including full floating point representations.

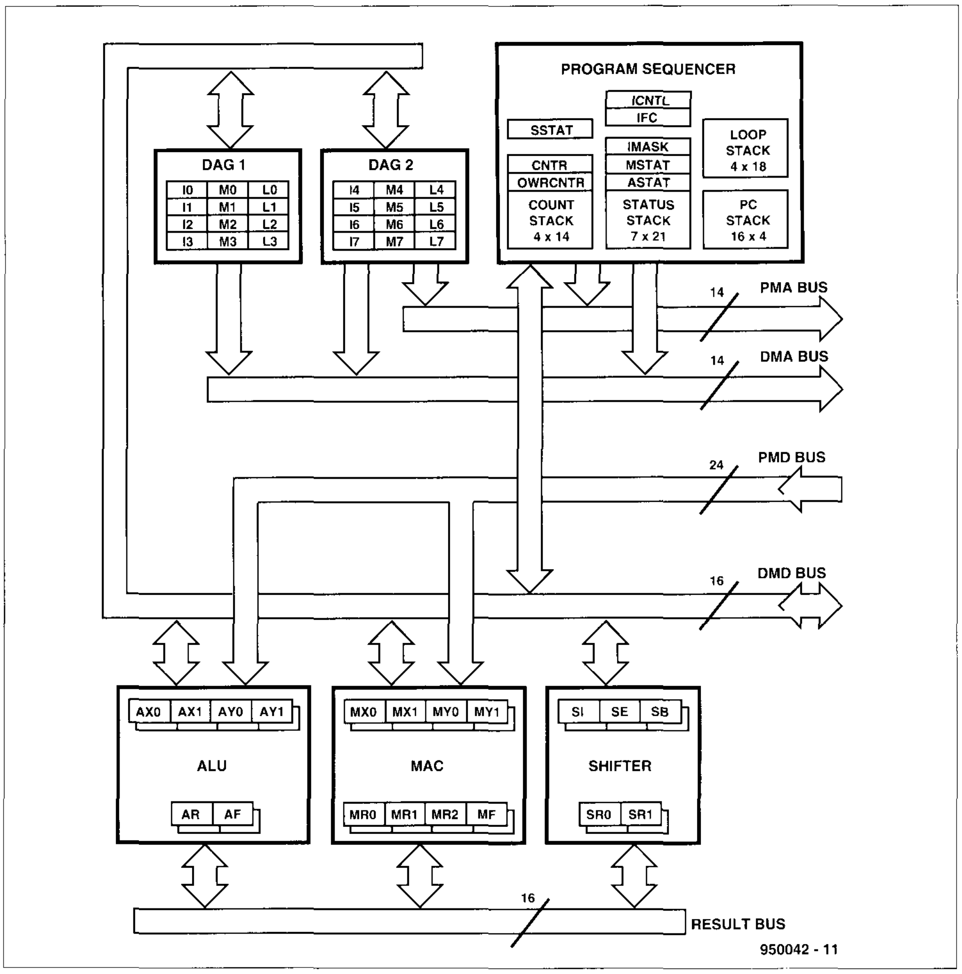

Fig. 1. Block diagram of the ADSP-2105.

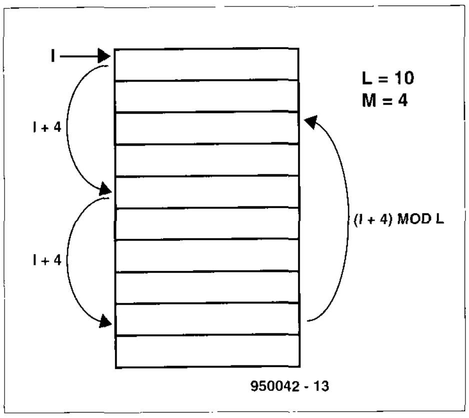

Fig. 2. When a register is scanned and an overflow occurs, the pointer is placed modulo L at the beginning of the register.

The computational units are arranged side by side instead of serially for flexible operation sequencing. The internal result (R) bus interconnects the units, so that the output of any one of them may be the input of any unit on the next cycle.

A powerful program sequencer and two dedicated data address generators ensure efficient use of these computational units. The program sequencer generates the next instruction address. To minimize overhead cycles, the seuqnecer supports conditional jumps, subroutine calls and returns in a single cycle. With internal loop counters and loop stacks, the DSP executes looped code with zero overhead; no explicit jump instructions are required to maintain the loop.

The data address generators (DAGs) handle address pointer updates. Each DAG keeps track of up to four address pointers. Whenever the pointer is used to access external data (indirect addressing), it is modified by a prespecified value. A length value may be associated with each pointer to implement automatic modulo addressing for circular buffers. With two independent DAGs, the processor can generate two addresses simultaneously for dual operand fetches.

Efficient data transfer is achieved with the use of five internal buses:

- Program Memory Address (PMA) bus;
- Program Memory Data (PMD) bus;
- Data Memory Address (DMA) bus;
- Data Mmeory Data (DMD) bus;
- Result (R) bus.

The program memory (PMA, PMD) buses and data memory (DMA, DMD) buses extend off-chip to provide direct connections to external memories.

The DMD bus is the primary bus for routeing data internally and to and from external data memory.

The 14-bit DMA bus provides direct addressing of 16k×16 of external memory. Although the primary function of the program memory is for storing instructions, it can also store data. In this case, the PMD bus provides a path for routeing data to and from program memory, permitting dual operand fetches.

The 14-bit PMA bus provides direct addressing of 16k×24 of external memory, expandable to 32k×24 by using the program memory data access (PMDA) signal as the 15th address line.

The data address generators provide indirect addressing for data stored in external memories. The processor contains two independent DAGs so that two data operands (one in program memory and one in data memory) can be addressed simultaneously.

The two generators are identical except that DAG1 has a bit reversal option on the output and can only generate data memory addresses, while DAG2 can generate both program and data memory address, but has no bit reversal capability.

There are three register files in each DAG: the modify (MO register file, the indirect (I) register file, and the length (L) register file. Each of these register files contains four 14-bit register which are readable and loadable from the DMD bus. The I registers hold the actual addresses used to access external memory.

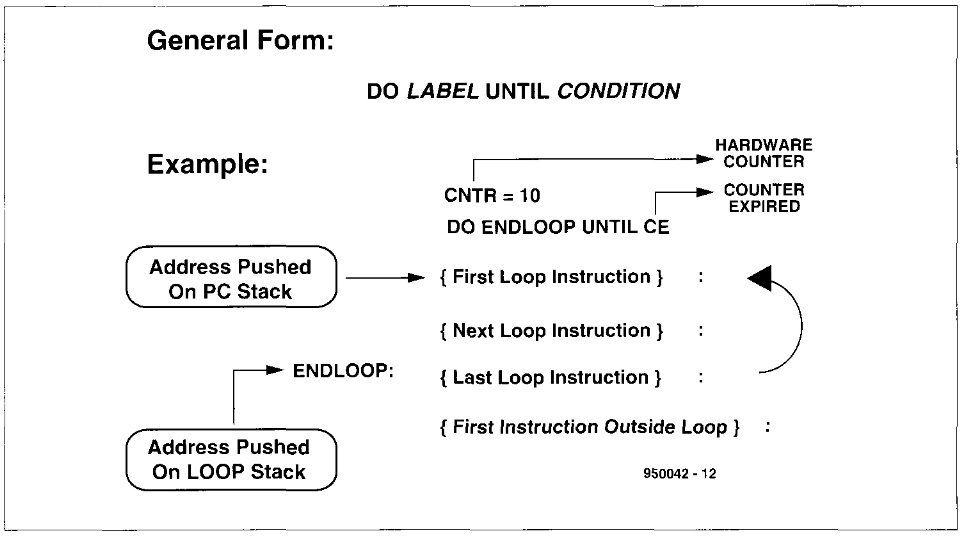
General Form:
DO *LABEL* UNTIL *CONDITION*
Example:
HARDWARE COUNTER
CNTR = 10
COUNTER EXPIRED
DO ENDLOOP UNTIL CE
Address Pushed On PC Stack
{ First Loop Instruction } :
{ Next Loop Instruction } :
ENDLOOP:
{ Last Loop Instruction } :
{ First Instruction Outside Loop } :
Address Pushed On LOOP Stack
950042 - 12

Fig. 2. Example of a DO–UNTIL loop in a DSP. The processor has a discrete loop counter.

When the indirect addressing mode is used, the selected I register content is driven on to either the PMA or DMA bus. This value is post-modified by adding the content of the selected M register. The modified address is passed through the modulus logic.

Associated with each I register is an L register which may contain the length of the buffer addressed by the I register. In case of an overflow, the pointer is placed modulo L at the beginning of the register—see **Fig. 2**. The L register and the modulus logic together enable circular buffer addressing, which is used, for example, in the DSP Function Generator described elsewhere in this issue for Direct Digital Synthesis DDS).

The modulus logic is disabled by setting the length of the associated buffer to zero.

The program sequencer incorporates powerful and flexible mechanisms for program flow control, such as zero-overhead looping, single-cycle branching (both conditional and unconditional) and automatic interrupt processing.

The sequencing logic controls the flow of the program execution. It outputs a program memory address on to the PMA bus from one of four sources: the PC incrementer, PC stack, instruction register or interrupt controller. The next address source selector controls which of these four sources are selected based on the current instruction word and the processor status. A fifth possible source for the next program memory address is provided by DAG2 when a register indirect jump is executed.

The loop counter is used for DO–UNTIL loops (see **Fig. 3**); there is thus no variable that needs to be checked bh the program, but a register that is automatically decreased and signals when the end condition (CNTR=0) is reached.

When a data fetch from program memory is required, an extra memory cycle is automatically appended to enable the next instruction fetch. To avoid this extra cycle, the device has an internal instruction cache (16 instructions deep) which serves an an alternate source for the next instruction. The cache monitor circuit transparently determines when the cache contents are valid. When the next instruction is in the cache, no extra cycle is necessary.

[950042]

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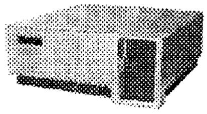
AT 286

40Mb HD + 3Mb Ram



LIMITED QUANTITY only of these **12Mhz HI GRADE 286** systems Made in the USA to an industrial specification, the system was designed for *total reliability.* The compact case houses the motherboard, PSU and EGA video card with single **5¼" 1.2 Mb** floppy disk drive & **integral 40Mb hard disk drive** to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with **enhanced keyboard, 640k + 2Mb RAM, DOS 4.01 and 90 DAY Full Guarantee.** *Ready to Run !*

Order as HIGRADE 286 ***ONLY £149.00*** (E)

CALL FOR QTY DISCOUNTS

Optional Fitted extras: VGA graphics card	**£29.00**
1.4Mb 3½" floppy disk drive (instead of 1.2 Mb)	**£32.95**
NE2000 Ethernet (thick, thin or twisted) network card	**£49.00**

PC SCOOP

COMPLETE

COLOUR SYSTEM

ONLY £99.00

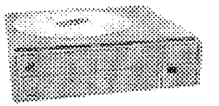
A massive bulk purchase enables us to bring you a **COMPLETE ready to run** colour PC system at an unheard of price! **The Display Electronics PC99 system** comprises of fully compatible and expandable XT PC with 256k of RAM, 5¼" 360k floppy disk drive, **12" CGA colour monitor**, standard 84 key keyboard, MS DOS and all connecting cables - **just plug in and go** !! Ideal students, schools or anybody wishing to learn the world of PC's on an ultra low budget. **Don't miss this opportunity.** Fully guaranteed for 90 Days.

Order as PC99COL **£99.00** (E)

Optional Fitted extras: 640k RAM	£29.00
2nd floppy drive, specify 5¼" 360k or 3½" 720k	£29.95

Above prices for PC99 offer ONLY.

SPECIAL OFFER



Computer Controlled

Laser Video Disk Player

One of the most **amazing** surplus deals that we ever been able to offer you! The **Philips VP410** LaserVision player, in as new condition, unit features full computer control, Plays standard 12" LaserVision disks with **startling visual and audio quality** in two channel **stereo** or mono. When controlled by a computer, it may also be used as a versatile high quality storage / retrieval medium. It will play back either LaserVision CAV (active play) or CLV (Long Play) discs (which covers most types of commercially available video discs). Some of the many features of this incredible machine are:

RS-232 INTERFACE	RGB / COMPOSITE VIDEO OUTPUT
BNC+SCART INTERFACE	PAL / RGB DECODER
IR+WIRED REMOTE CONTROL	FAST RANDOM ACCESS

SPECIAL PURCHASE Only **£399.00** (F)

FLOPPY DISK DRIVES 3.5"- 8"

5.25" from £22.95 - 3.5" from £24.95

Massive purchases of standard 5.25" and 3.5" drives enables us to present prime product at industry beating low prices! All units (unless stated) are ***BRAND NEW*** or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. **All are IBM-PC compatible** (if 3.5" supported on your PC).

3.5" **Panasonic** JU363/4 720K or equivalent	**£24.95**(B)
3.5" **Mitsubishi** MF355C-L. 1.4 Meg. Laptops only *	**£36.95**(B)
3.5" **Mitsubishi** MF355C-D. 1.4 Meg. Non laptop	**£29.95**(B)
5.25" **Teac** FD-55GFR 1.2 Meg	**£29.95**(B)
5.25" **BRAND NEW Mitsubishi** MF501B 360K	**£22.95**(B)

* Data cable included in price.

Shugart 800/801 8" SS refurbished & tested	**£195.00**(E)
Shugart 851 8" double sided refurbished & tested	**£250.00**(E)
Mitsubishi M2894-63 8" double sided *NEW*	**£275.00**(E)
Mitsubishi M2896-63-02U 8" DS slimline *NEW*	**£285.00**(E)

Dual 8" drives with 2 mbyte capacity housed in a smart case with built in power supply. Ideal as exterior drives! **£499.00**(F)

HARD DISK DRIVES

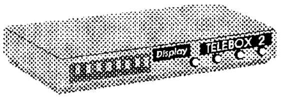
End of line purchase scoop! Brand new **NEC D2246** 8" 85 Mbyte of hard disk storage! Full **industry standard SMD interface.** Ultra hi speed data transfer and access time, replaces Fujitsu equivalent model. complete with manual. Only **£299.00**(E)

3.5" **FUJI** FK-309-26 20mb MFM I/F RFE	**£59.95**(C)
3.5" **CONNER** CP3024 20 mb IDE I/F (or equiv)RFE	**£69.95**(C)
3.5" **CONNER** CP3044 40mb IDE I/F (or equiv.)RFE	**£89.00**(C)
3.5" **RODIME** RO3057S 45mb SCSI I/F (Mac & Acorn)	**£99.00**(C)
5.25" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	**£49.95**(C)
5.25" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	**£69.95**(C)
5.25" **CDC** 94205-51 40mb HH MFM I/F RFE tested	**£69.95**(C)
8" **FUJITSU** M2322K 160Mb SMD I/F RFE tested	**£195.00**(E)

Hard disc controllers for MFM , IDE, SCSI, RLL etc. **from £16.95**

THE AMAZING TELEBOX

Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND & VIDEO TUNER!

The **TELEBOX** consists of an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as **MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD** etc. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers* (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. **TELEBOX MB** covers virtually all television frequencies VHF and UHF **including the HYPERBAND as used by most cable TV operators.** A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard.

TELEBOX ST for composite video input type monitors	**£34.95**
TELEBOX STL as ST but with integral speaker	**£37.50**
TELEBOX MB Multiband VHF-UHF-Cable- Hyperband tuner	**£69.95**

For overseas PAL versions state 5.5 or 6mhz sound specification.
*For cable / hyperband reception Telebox MB should be connected to cable type service. Shipping code on all Teleboxes is (B)

FANS & BLOWERS

MITSUBISHI MMF-D6D12DL 60 x 25 mm 12v DC	**£4.95 10 / £42**
MITSUBISHI MMF-09B12DH 92 x 25 mm 12v DC	**£5.95 10 / £53**
PANCAKE 12-3.5 92 x 18 mm 12v DC	**£7.95 10 / £69**
EX-EQUIP 120 x 38mm AC fans - tested specify 110 or 240 v	**£6.95**
EX-EQUIP 80 x 38mm AC fans - tested specify 110 or 240 v	**£5.95**
VERO rack mount 1U x 19" fan tray specify 110 or 240v	**£45.95** (B)
IMHOF B26 1900 rack mnt 3U x 19" Blower 110/240v NEW	**£79.95**

Shipping on all fans (A). Blowers (B). ***50,000 Fans Ex Stock CALL***

IC's -TRANSISTORS - DIODES

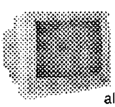
OBSOLETE - SHORT SUPPLY - BULK

5,000,000 items EX STOCK

For *MAJOR SAVINGS* - SAE or CALL FOR LATEST LIST

VIDEO MONITOR SPECIALS

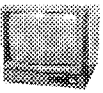
Superb quality 14" **FOREFRONT MTS-9600 SVGA** Multisync - Multimode monitor 0.28" dot pitch with resolution of **1024 x 768.** The multi mode input allows direct connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** etc. The H version will also function with the **ATARI** in all modes inc **HI RES monochrome.** Complete with 'text' switching for WP use.(possible minor screen bums) Syncs down to 15 kHz. Supplied in EXCELLENT little used condition with full 90 day guarantee.



Order as MTS-9600 / H for ATARI	**£149.00** (E)
All modes as above Order as MTS-9600 / S	**£129.00** (E)

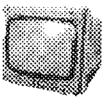
ELECTROHOME ECM-1211SBU 12" VGA multisync monitor with resolution 640 x 480. Multi input selection; 9pin CGA/ EGA ; 15 pin VGA or 5 BNC connectors. 0.31 pitch. Compatible with PCs, Amiga, Atari and others. In good used condition (possible minor screen bums)90 day guarantee. ..... **£99.00** (E)

KME 10" high definition colour monitors. Nice tight 0.28" dot pitch for superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13.5" x 12" x 11". **Only £125** (E) Good used condition. 90 day guarantee.



KME 10" as above for PC EGA standard £145.00 (E)

NEC CGA 12" colour IBM-PC compatible. High quality ex-equipment fully tested with a 90 day guarantee. In an attractive two tone ribbed grey plastic case measuring 15"L x 13"W x 12"H. The front cosmetic bezel has been removed for contractual reasons.



Only £49.00(E)

20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. PIL all solid state colour monitors, complete with composite video & optional sound inputs. Attractive teak style case. Perfect for Schools, Shops, Disco, Clubs, etc.In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

12" Mono. Philips BM7542 /05G for CCTV **NEW £69.95** (C)

DC POWER SUPPLIES

10,000 Power Supplies Ex Stock
Call for info / list

Power One SPL200-5200P 200 watt (250 w peak).Semi open frame giving +5v 35a, -5v 1.5a, +12v 4a (8a peak), -12v 1.5a, +24v 4a (6a peak). All outputs fully regulated with over voltage protection on the +5v output. AC input selectable for 110/240 vac. Dims13" x 5" x 2.5". Fully guaranteed RFE. **£85.00**(B)

Power One SPL130. 130 watts. Selectable for 12v (4A) or 24 v (2A). 5v @ 20A. & 12v @ 1.5A. Switch mode.New. **£59.95**(B)

Astec AC-8151 40 watts. Switch mode. +5v @ 2.5a. +12v @ 2a. -12v @ 0.1a. 6-1/4" x 4" x 1-3/4" RFE tested **£22.95**(B)

Lambada LYS-PV-12 200 watt switch mode.**+12V DC @ 29a** semi enclosed, 10" x 5" x 5". RFE and fully tested. **£59.95**(C)

Conver AC130. 130 watt hi-grade VDE spec.Switch mode.+5v @ 15a,-5v @ 1a,+12v @ 6a.27 x 12.5 x 6.5cms.New. **£49.95**(C)

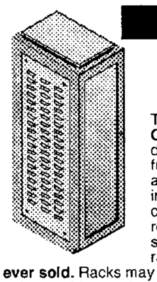
Boshert 13090.Switch mode.Ideal for drives & system. +5v@ 6a, +12v @ 2.5a, -12v @ 0.5a, -5v @ 0.5a. **£29.95**(B)

Farnell G6/40A. Switch mode. 5v @ 40a.Encased **£95.00**(C)

SPECIAL INTEREST

INTEL SBC 486/133SE Multibus 486 system. 8Mb Ram	**£1975**
Zeta 3220-05 A0 4 pen **HPGL** RS232 fast drum plotter	**£1950**
3M VDA - Video Distribution Amps.1 in 32 out	**£375**
Trio 0-18 vdc bench PSU. 30 amps. New	**£470**
Fujitsu M3041 600 LPM band printer	**£1950**
VG Electronics 1035 TELETEXT Decoding Margin Meter	**£3750**
Andrews LARGE 3.1 m Satellite Dish + mount (For Voyager!)	**£950**
RED TOP IR Heat seeking missile (not armed !!)	**POA**
Tektronix 1L30 Spectrum analyser plug in	**£330**
Thurlby LA 160B logic analyser	**£375**
GEC 1.5kw 115v 60hz power source	**£950**
Brush 2Kw 400 Hz 3 phase frequency converter	**£850**
Anton Pillar 75 kW 400 Hz 3 phase frequency converter	**POA**
Newton Derby 70 KW 400 Hz 3 phase frequency converter	**POA**
Nikon PL-2 Projection lens meter/scope	**£750**
Sekonic SD 150H 18 channel digital Hybrid chart recorder	**£1995**
HP 7580A A1 8 pen HPGL high speed drum plotter	**£1850**
Kenwood DA-3501 CD tester, laser pickup simulator	**£350**
Computar MCA1613APC 16mm auto iris lenses 'C' mount	**£125**
Seaward PAT 2000 dual voltage computerised PAT tester	**£585**

19" RACK CABINETS



Superb quality 6 foot 40U
Virtually New, Ultra Smart
Less than Half Price!

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the **most versatile we have ever sold.** Racks may be stacked side by side and therefore require only two side panels to stand singly or in bays

Overall dimensions are: 77-1/2" H x 32-1/2" D x 22" W. **Order as:**

OPT Rack 1 Complete with removable side panels.	**£335.00** (G)
OPT Rack 2 Rack, Less side panels	**£225.00** (G)

Over 1000 racks in all sizes 19" 22" & 24"
3 to 44 U. Available from stock !!
Call with your requirements.

TOUCH SCREEN SYSTEM

The ultimate in '**Touch Screen Technology**' made by the experts - ***MicroTouch*** - but sold at a **price below cost** !! System consists of a flat translucent glass laminated panel measuring 29.5 x 23.5 cm connected to a PCB with on board sophisticated electronics. From the board comes a **standard serial RS232** or TTL output. The output continuously gives simple serial data containing positional X & Y co-ordinates as to where a finger is touching the panel - as the finger moves, the data instantly changes. The X & Y information is given at an **incredible matrix resolution of 1024 x 1024** positions over the screen size !!! So, no position, however small fails detection. **A host of available translation software** enables direct connection to a PC for a myriad of applications including: control panels, pointing devices, POS systems, controllers for the disabled or computer un-trained etc etc Imagine using your finger in 'Windows' instead of a mouse !! (a driver is indeed available !) ***The applications for this amazing product are only limited by your imagination!!*** Supplied as a complete system including Controller, Power Supply and Data at an incredible price of only:

RFE. Full Software Support Available - Fully Guaranteed ***£145.00*** (B)

LOW COST RAM & CPU'S

INTEL 'ABOVE' Memory Expansion Board. Full length PC-XT and PC-AT compatible card with **2 Mbytes** of memory on board. Card is fully selectable for Expanded or Extended (286 processor and above) memory. **Full data and driver disk supplied.** In good used condition fully tested and guaranteed.

Windows compatible. **Order as: ABOVE CARD** **£59.95**(A1)

Half length 8 bit memory upgrade cards for PC AT XT expands memory either 256k or 512k in 64k steps. May also be used to fill in RAM above 640k DOS limit. Complete with data.

Order as: XT RAM UG. 256k. £32.95 *or* **512k £38.95** (A1)

1 MB x 9 SIMM 9 chip 120ns	only	**£19.50**	(A1)
1 MB x 9 SIMM 3 chip 80 ns	only	**£23.50**	(A1)
1 MB x 9 SIMM 9 chip 80 ns	only	**£22.50**	(A1)
4 MB 70ns 72 pin simm module	only	**£89.00**	(A1)
***SPECIAL* INTEL 486-DX33 CPU**	*few only*	**£79.99**	(A1)

NO BREAK UNINTERRUPTIBLE PSU'S

Brand new and boxed 230 volts 1 KVa uninterruptible power supply system from **Densei. Model MUD 1085-AHBH.** Complete with sealed lead acid batteries in matching case. Approx time from interrupt is 15 minutes. Complete with full manual. **£575.00**(G)

EMERSON ACCUCARD UPS, brand new 8 Bit half length PC compatible card for all **IBM XT/AT** compatibles. Card provides DC power to all internal system components in the event of power supply failure.The Accusaver software provided uses only 6k of base RAM and automatically copies **all** system, expanded and video memory to the hard disk in the event of loss of power. When power is returned the machine is returned to the **exact status when the power failed** !! The unit features full self diagnostics on boot and is supplied **brand new**, with full, easy fitting instructions and manual.

Normally £189.00 ***NOW!*** **£69.00 or 2 for £120** (B)

Issue 13 of *Display News* now available - send large SAE - PACKED with bargains!

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74LS11	£0.17
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74LS113	£0.21
74LS114	£0.21
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74LS122	£0.31
74LS123	£0.31
74LS125	£0.21
74LS126	£0.21
74LS13	£0.14
74LS132	£0.21
74LS133	£0.18
74LS136	£0.16
74LS138	£0.24
74LS139	£0.25
74LS14	£0.18
74LS145	£0.56
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74LS148	£0.70
74LS15	£0.14
74LS151	£0.25
74LS153	£0.25
74LS154	£0.70
74LS155	£0.25
74LS156	£0.36
74LS157	£0.25
74LS158	£0.25
74LS160	£0.32
74LS161	£0.32
74LS162	£0.32
74LS163	£0.32
74LS164	£0.26
74LS165	£0.48
74LS170	£0.30
74LS173	£0.24
74LS174	£0.24
74LS175	£0.24
74LS190	£0.25
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74LS192	£0.42
74LS193	£0.24
74LS195	£0.24
74LS196	£0.24
74LS197	£0.24
74LS20	£0.16
74LS21	£0.14
74LS22	£0.14
74LS221	£0.36
74LS240	£0.32
74LS241	£0.32
74LS242	£0.32
74LS243	£0.32
74LS244	£0.32
74LS245	£0.36
74LS247	£0.32
74LS251	£0.24
74LS257	£0.24
74LS258	£0.24
74LS26	£0.14
74LS266	£0.14
74LS27	£0.14
74LS273	£0.32
74LS279	£0.25
74LS30	£0.14
74LS32	£0.14
74LS365	£0.21
74LS367	£0.21
74LS368	£0.21
74LS37	£0.14
74LS373	£0.32
74LS374	£0.32
74LS375	£0.34
74LS377	£0.32
74LS378	£0.62
74LS38	£0.14
74LS390	£0.25
74LS393	£0.24
74LS395	£0.26
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74LS40	£0.14
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4011	£0.26
4012	£0.16
4013	£0.21
4014	£0.30
4015	£0.31
4016	£0.18
4017	£0.27
4018	£0.27
4019	£0.19
4020	£0.31
4021	£0.31
4022	£0.32
4023	£0.16
4024	£0.21
4025	£0.15
4026	£0.59
4027	£0.18
4028	£0.22
4029	£0.36
4030	£0.17
4031	£0.70
4033	£0.56
4034	£1.24
4035	£0.31
4040	£0.29
4041	£0.31
4042	£0.22
4043	£0.28
4044	£0.35
4046	£0.31
4047	£0.48
4048	£0.31
4049	£0.20
4050	£0.20
4051	£0.36
4052	£0.25
4053	£0.25
4054	£0.56
4055	£0.34
4060	£0.48
4063	£0.29
4066	£0.18
4067	£1.91
4068	£0.16
4069	£0.20
4070	£0.17
4071	£0.20
4072	£0.17
4073	£0.17
4075	£0.17
4076	£0.30
4077	£0.17
4081	£0.14
4082	£0.21
4085	£0.28
4086	£0.26
4089	£0.55
4093	£0.30
4094	£0.31
4095	£0.56
4097	£1.20
4098	£0.48
4099	£0.38
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4512	£0.32
4514	£0.77
4515	£0.98
4516	£0.31
4518	£0.27
4520	£0.26
4521	£0.62
4526	£0.40
4527	£0.40
4528	£0.40
4529	£0.44
4532	£0.32
4534	£2.48
4536	£1.00
4538	£0.37
4541	£0.33
4543	£0.46
4555	£0.34
4556	£0.34
4560	£1.18
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2N2219A	£0.25	BC208	£0.72	BD648	£0.52
2N2222A	£0.16	BC209A	£0.72	BD650	£0.53
2N2646	£0.80	BC212	£0.08	BD707	£0.42
2N2904A	£0.25	BC212L	£0.08	BD807	£0.80
2N2905A	£0.23	BC212LB	£0.08	BDX32	£1.78
2N2907	£0.20	BC213	£0.08	BDX33C	£0.46
2N2926	£0.16	BC213LC	£0.08	BDX34C	£0.50
2N3053	£0.27	BC214	£0.08	BDX53C	£0.47
2N3054	£0.90	BC214L	£0.08	BDX54C	£0.50
2N3055	£0.62	BC237B	£0.09	BF180	£0.31
2N3440	£0.50	BC238C	£0.09	BF182	£0.31
2N3702	£0.09	BC239C	£0.10	BF185	£0.31
2N3703	£0.10	BC251	£0.13	BF194	£0.19
2N3704	£0.10	BC252	£0.13	BF195	£0.19
2N3705	£0.10	BC261B	£0.24	BF244	£0.35
2N3706	£0.10	BC262B	£0.24	BF257	£0.33
2N3771	£1.44	BC267B	£0.30	BF259	£0.33
2N3772	£1.51	BC307	£0.10	BF337	£0.36
2N3773	£1.79	BC308	£0.10	BF355	£0.38
2N3819	£0.40	BC327	£0.10	BF423	£0.13
2N3820	£0.58	BC328	£0.10	BF451	£0.19
2N3904	£0.10	BC337	£0.10	BF459	£0.33
2N3905	£0.10	BC338	£0.10	BF469	£0.36
2N3906	£0.10	BC414C	£0.13	BFX29	£0.29
2N4036	£0.31	BC441	£0.40	BFX84	£0.31
2N5296	£0.57	BC461	£0.40	BFX85	£0.31
2N5321	£0.57	BC463	£0.29	BFY50	£0.29
2N6107	£0.60	BC478	£0.32	BFY51	£0.26
AC126	£0.30	BC479	£0.32	BFY52	£0.28
AC127	£0.30	BC490	£0.24	BS107	£0.21
AC128	£0.28	BC516	£0.22	BS170	£0.21
AC187	£0.45	BC517	£0.20	BSW66	£1.35
AC188	£0.37	BC527	£0.20	BU126	£1.70
ACY17	£3.84	BC528	£0.20	BU205	£1.82
AD149	£1.67	BC537	£0.20	BU208A	£1.73
AD161	£0.92	BC546C	£0.08	BU326A	£1.80
AD162	£0.92	BC547C	£0.09	BU500	£2.32
BC107	£0.14	BC548C	£0.08	BU508A	£1.76
BC107B	*£0.15*	*BC549C*	*£0.10*	BU526	£2.24
BC108	£0.14	BC550C	£0.08	BU806	£1.36
BC108A	£0.14	BC556A	£0.08	BUX84	£0.78
BC108C	£0.16	BC557C	£0.08	IRF540	£1.60
BC109	£0.14	BC558C	£0.08	IRF740	£1.80
BC109C	£0.17	BC559C	£0.08	MJ11015	£2.11
BC114	£0.41	BC560B	£0.09	MJ11016	£2.11
BC115	£0.41	BC637	£0.21	MJ2501	£1.60
BC116	£0.41	BC638	£0.21	MJ3001	£1.52
BC118	£0.41	BC639	£0.21	MJE340	£0.40
BC132	£0.36	BC640	£0.21	MJE350	£0.42
BC134	£0.36	BCY70	£0.21	MPSA13	£0.12
BC135	£0.36	BCY71	£0.20	MPSA42	£0.17
BC140	£0.25	BCY72	£0.20	MRF475	£6.21
BC141	£0.27	BD135	£0.20	TIP121	£0.35
BC142	£0.31	BD136	£0.21	TIP122	£0.40
BC143	£0.34	BD137	£0.22	TIP125	£0.37
BC149	£0.21	BD138	£0.22	TIP127	£0.37
BC154	£0.36	BD139	£0.23	TIP132	£0.46
BC157	£0.12	BD140	£0.24	TIP137	£0.46
BC159	£0.12	BD150C	£0.82	TIP142	£1.08
BC160	£0.28	BD165	£0.42	TIP147	£1.12
BC170	£0.16	BD166	£0.35	TIP2955	£0.63
BC170B	£0.16	BD187	£0.39	TIP29C	£0.31
BC171	£0.11	BD201	£0.40	TIP3055	£0.63
BC171B	£0.16	BD202	£0.40	TIP30C	£0.31
BC172	£0.13	BD203	£0.40	TIP31C	£0.34
BC172B	£0.13	BD204	£0.40	TIP32C	£0.32
BC177	£0.18	BD222	£0.40	TIP33C	£0.72
BC178	£0.18	BD225	£0.42	TIP41A	£0.48
BC179	£0.17	BD232	£0.38	TIP42C	£0.38
BC182	£0.08	BD237	£0.32	TIP47	£0.48
BC182L	£0.08	BD238	£0.32	TIP48	£0.62
BC182LB	£0.08	BD240B	£0.37	TIP50	£0.53
BC183	£0.08	BD243B	£0.50	VN10KM	£0.44
BC183L	£0.08	BD244A	£0.53	VN66AF	£1.50
BC183LB	£0.08	BD246	£1.06	ZTX300	£0.16
BC184	£0.08	BD441	£0.41	ZTX500	£0.16
BC184L	£0.08	BD442	£0.41		

LINEAR ICs

CA311E	£0.28
CA324	£0.35
CA555	£0.22
CA741CE	£0.28
CA747CE	£0.39
CA3046	£0.37
CA3080	£0.72
CA3130	£0.98
CA3130E	£0.98
CA3140	£0.56
CA3240	£1.12
ICL7621	£1.70
ICM7555	£0.43
ICM7556	£0.96
LM301A	£0.25
LM348N	£0.31
LF351N	£0.36
LF353	£0.41
LF356	£0.84
LM358N	£0.27
LM377	£2.57
LM380N	£1.12
LM381	£2.70
LM386	£0.48
LM387	£1.60
LM392N	£0.79
LM393N	£0.28
LM748CN	£0.31
LM1458	£0.26
LM3900	£0.72
LM3914	£2.70
LM3915	£2.70
MC3340	£1.60
MC4558	£0.36
NE531	£1.56
NE556N	£0.36
NE567N	£0.36
NE5532	£0.80
NE5534	£0.66
TBA120S	£0.77
TBA810S	£0.68
TBA820M	£0.39
TDA2030	£1.35
TL061	£0.35
TL062	£0.42
TL064	£0.46
TL071CP	£0.32
TL072CP	£0.34
TL074CN	£0.48
TL081	£0.33
TL082CP	£0.34
TL084CN	£0.46
UA733	£0.64
ULN 2003	£0.52
ULN2004	£0.48
ZN414Z	£1.04
ZN425E	£4.68
ZN426E	£2.61
ZN427E	£8.82
ZN428E	£6.12
ZN435E	£5.31
ZN448E	£7.92

EPROMS & RAMS

2716	£4.46
2732	£4.84
2764-25	£3.00
27C64-25	£2.80
21728-20	£3.69
27C128-20	£3.31
27256-20	£3.99
27C256-20	£3.57
27C512	£3.69
27C010	£4.97
6116-10	£1.53
6264-10	£3.06
62256-10	£4.83
4164-15	£1.78
41256-10	£2.80
511000-8	£5.61
514256-8	£5.61

DIL SOCKETS

8 Pin	£0.07
14 Pin	£0.11
16 Pin	£0.15
18 Pin	£0.15
20 Pin	£0.16
24 Pin	£0.19
28 Pin	£0.22
40 Pin	£0.25

TRIACS

Z0105DA	£0.42
TIC206D	£0.65
TIC226D	£0.73
BTA08-600B	£0.84
TIC236D	£0.96
DIAC	£0.20

THYRISTORS

PO102AA	*£0.30*
TIC106D	£0.40
TIC116D	£0.66
TIC126D	£0.77

VOLTAGE REGULATORS

78L05	£0.24
78L12	£0.24
78L15	£0.24
79L05	£0.28
79L12	£0.28
79L15	£0.28
7805	£0.28
7812	£0.28
7815	£0.28
7905	£0.38
7912	£0.38
7915	£0.38
LM317T	£0.65
LM723	£0.29
L200CV	£1.16
LM323K	£2.70
LM338K	£5.52

HARDWARE

T2 Box 75 x 56 x 25mm	£0.82
T3 Box 75 x 51 x 25mm	£0.82
T4 Box 111 x 57 x 22mm	£0.98
MB1 Box 79 x 61 x 40mm	£1.44
MB2 Box 100 x 76 x 41mm	£1.56
MB3 Box 118 x 98 x 45mm	£1.82
MB5 Box 150 x 100 x 60mm	£2.50

ELECTROLYTIC RADIAL CAPACITORS

uF	16V	25V	63V	100V	450V
0.47	-	-	£0.05	£0.07	-
1.0	-	-	£0.05	£0.06	£0.15
2.2	-	-	£0.05	£0.06	£0.18
4.7	-	-	£0.05	£0.08	£0.30
10	£0.05	£0.05	£0.06	£0.08	£0.48
22	£0.05	£0.05	£0.09	-	-
47	£0.06	£0.06	£0.11	-	-
100	£0.06	£0.09	£0.11	-	-
220	£0.09	£0.12	£0.31	-	-
470	£0.15	£0.19	£0.57	-	-
1000	£0.22	£0.29	-	-	-
2200	£0.37	£0.57	-	-	-
4700	-	£1.11	-	-	-

ELECTROLYTIC AXIAL CAPACITORS

uF	16V	25V	63V	100V	450V
0.47	-	-	-	£0.15	-
1.0	-	-	£0.10	£0.10	£0.19
2.2	-	-	£0.10	£0.10	£0.22
4.7	-	£0.09	£0.10	£0.10	£0.34
10	-	£0.12	£0.12	£0.12	£0.48
22	-	£0.09	£0.13	£0.17	£1.06
47	£0.10	£0.11	£0.16	£0.20	£1.33
100	£0.10	£0.13	£0.21	-	£2.46
220	£0.13	£0.18	£0.42	-	-
470	£0.21	£0.24	£0.69	-	-
1000	£0.33	£0.40	£1.05	-	-
2200	£0.52	£0.64	-	-	-
4700	£0.90	-	-	-	-

ENAMELLED COPPER WIRE

All 2oz Reels

14 SWG	£0.63
16 SWG	£0.67
18 SWG	£0.67
20 SWG	£0.72
22 SWG	£0.76
24 SWG	£0.80
26 SWG	£0.89
28 SWG	£0.91
30 SWG	£0.93
32 SWG	£0.93
34 SWG	£0.99
36 SWG	£1.04
38 SWG	£1.10
40 SWG	£1.22

OPTO DEVICES

5mm Red LED	£0.09
5mm Green LED	£0.10
5mm Yellow LED	£0.10
5mm Orange LED	£0.10
3mm Red LED	£0.08
3mm Green LED	£0.12
3mm Yellow LED	£0.13
3mm Orange LED	£0.13
5mm Flashing Red	£0.50
5mm Flashing Green	£0.54
5mm Bi Colour	£0.36
5mm Tri Colour	£0.48
5mm Plastic Bezel	£0.04
3mm Plastic Bezel	£0.05
0.3" 7 Segment Display Red	
common anode	£1.14
common cathode	£1.14

SOLDERING IRONS

Antex Soldering irons

M 12 Watt	£8.50
C 15 Watt	£8.19
G 18 Watt	£8.75
CS 17 Watt	£8.65
XS 25 Watt	£8.75
GASCAT	15.87
ST4 STAND	£2.85
35Watt Gas Iron	£11.58
Desolder Pump	£3.00
Antistatic Pump	£4.30
22SWG 0.5Kg Solder	£7.40
18SWG 0.5Kg Solder	£6.60
1mm 3 yds Solder	£0.62
Desolder Braid	£0.87

RF CONNECTORS

BNC Solder Plug 50R	£0.93
BNC Solder Plug 75R	£0.96
BNC Crimp Plug 50R	£0.68
BNC Crimp Plug 75R	£0.68
BNC Solder Skt	£1.08
BNC Chassis Skt	£0.80
PL259 5.2mm	£0.68
PL259 11mm	£0.62
RND UHF socket	£0.68
SQR UHF socket	£0.45
F Plug RG58	£0.30
F Plug RG6	£0.27
N Plug RG8	£1.60
N Socket RG8	£1.40
BNC Crimp Pliers	£15.50

PCB EQUIPMENT

UV EXPOSURE UNIT	£67.38
PLASTIC DEVELOPING TRAY	£1.35
PHOTO RESIST AEROSOL SPRAY (100ml)	£3.90
FERRIC CHLORIDE CRYSTALS (0.5Kg)	£2.45
TIN PLATING POWDER (90g)	£10.80
ETCH RESIST PEN	£0.72
PCB POLISHING BLOCK	£1.84

STRIPBOARD 0·1 PITCH

64mm x 25mm	£0.27
64mm x 95mm	£0.90
64mm x 431mm	£3.22
95mm x 127mm	£1.50
95mm x 95mm	£1.10
95mm x 431mm	£4.80
100mm x 160mm	£1.60
119mm x 454mm	£6.20

BREADBOARD

81mm x 60mm	£3.06
175mm x 42mm	£3.74
175mm x 67mm	£5.56
203mm x 75mm includes mounting plate & posts	£7.36

COPPER BOARD (G. Fibre)

100mm x 160mm	£0.90
110mm x 220mm	£1.24

PHOTO RESIST BOARD (G. Fibre)

3" x 4"	£0.86
4" x 6"	£1.62
4" x 8"	£2.09
6" x 6"	£2.41

PHOTO RESIST BOARD (Paper)

3" x 4"	£0.67
4" x 6"	£1.24
4" x 8"	£1.58
8" x 10"	£4.63

CAPACITORS

Ceramic Mini Disc 100 & 63V
1.0pF to 100nF
1pF-1nF **£0.06**, 1n2-2n7 **£0.07**,
3n3-4n7 **£0.12**,
10n & 12n **£0.07**
Polystyrene 160V 5% 47pF to 10nF
47p-2n2 **£0.09**, 2n7-10n **£0.12**

D CONNECTORS

	Plug	Socket
9 Pin	£0.29	£0.30
15 Pin	£0.39	£0.39
15 Pin H.D.	£0.81	£0.90
23 Pin	£0.40	£0.49
25 Pin	£0.48	£0.50
9 Way plastic cover		£0.30
15 Way plastic cover		£0.33
23 Way plastic cover		£0.36
25 Way plastic cover		£0.36

SWITCHES

3amp 250v 6.4mm ⌀ mounting

SPST Toggle	£0.58
SPDT Toggle	£0.60
SPDT CO Tog	£0.64
DPDT Toggle	£0.68
DPDT CO Toggle	£0.76
DPDT CO Toggle (biased)	£1.20
DPDT CO Toggle (biased 1 way)	£1.20
DPDT mini slide	£0.15
Rotary Wafer 1P-12W, 2P-6W, 3P-4W, 4P-3W	£0.78
Key Switch SPST	£2.70
Push to make	£0.25
Push to break	£0.28
Latching Push Sqr	£0.63
PCB Tact 6 x 6mm	£0.25

BRIDGE RECTIFIERS

W005 1.5A 50V	£0.19
WO2 1.5A 200V	£0.20
BR32 3A 200V	£0.36
BR62 6A 200V	£0.70
1004 10A 400V	£1.39

RESISTORS

0.25W 5% CF E12 Series	**£0.60**/100
0.5W 5% CF E12 Series	**£0.95**/100
0.25W 1% MF E24 Series	**£1.72**/100
POTS Log or Lin 470R - 1MO 25mm dia 0.25in shaft	£0.42
PRESETS Enclosed Horz or Vert 100R - 1MO 0.15W	£0.15
PRESETS Skeleton Horz or Vert 100R - 1MO 0.1W	£0.11

★ PLEASE STATE VALUE REQUIRED ★

COMPUTER ACCESSORIES

Parallel Printer Lead 2m	£6.90
RS232 Lead (all pins) Male - Male	£3.75
RS232 Lead (all pins) Female - Male	£3.80
Centronics 36 Way Lead Male - Male	£4.78
Gender Changers	
9 Way D Mini Female to Female	£1.81
9 Way D Mini Male to Male	£1.98
25 Way D Mini Female to Female	£2.23
25 Way D Mini Male to Male	£2.23
9 Way D Female to Female	£2.33
9 Way D Male to Male	£2.33
25 Way D Female to Female	£2.71
25 Way D Male to Male	£2.71
Adaptors	
9 Way Male to 25 Way Female	£2.71
9Way Female to 25Way Male	£2.71
25 Way Male to 9 Way Female	£2.33
25 Way D Male to 36 Way Centronic	£3.56
25 *Way Null Modem Female - Female*	£3.02
25 Way Null Modem Male to Female	£3.02
25 Way Null Modem Male to Male	£3.02
RS232 Surge Protector Male - Female	£6.12
RS232 Jumper Box Male to Female	£3.02
RS232 Tester (7 LEDs) Male - Female	£6.59
Data Switch Boxes	
Serial Switch box - 2 Way A/B	£9.20
Serial Switch box - 3 Way A/B/C	£13.16
Serial Switch box 4 Way A/B/C/D	£15.15
Serial Switch box - Cross over	£19.69
Parallel box - 2 Way A/B	£11.84
Parallel box - 3 Way A/B/C/	£17.11
Parallel box - 4 Way A/B/C/D	*£18.43*
Parallel box - Cross over	£20.42

DIODES

Zener Diodes 2V7-33V

BZY88400Mw	£0.08
BZX85 1.3W	£0.14
1N4001	£0.06
1N4002	£0.07
1N4003	£0.07
1N4004	£0.07
1N4005	£0.07
1N4006	£0.08
1N4007	£0.08
1N5400	£0.09
1N5401	£0.09
1N5402	£0.09
1N5404	£0.11
1N5406	£0.11
1N5407	£0.14
1N5408	£0.15
1N914	£0.06
1N916	£0.06
1N4148	£0.05
BY133	£0.13
OA47	£0.28
OA90	£0.07
OA91	£0.10
OA202	£0.29
BA157	£0.10
BA158	£0.10
BA159	£0.10
1N4149	£0.06
OA200	£0.10

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VISA

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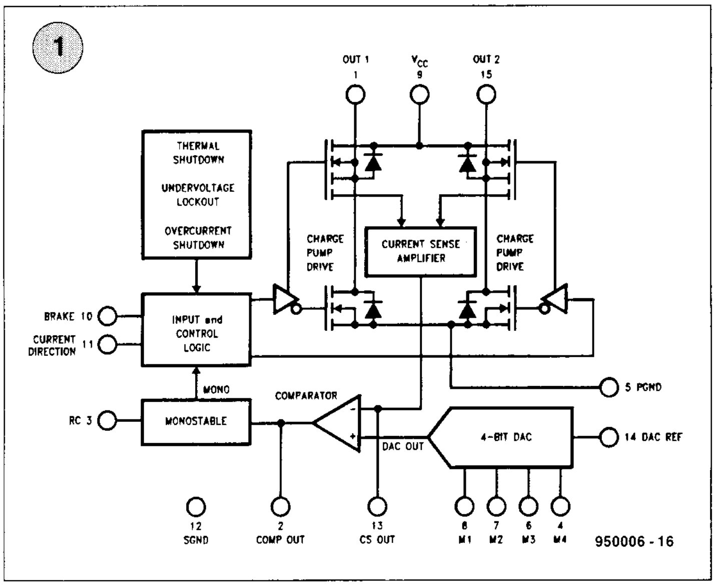
APPLICATION NOTE

The content of this article is based on information obtained from manufacturers in the electrical and electronics industries, and does not imply practical experience by *Elektor Electronics* or its consultants.

LMD18245 3A, 55V DMOS FULL-BRIDGE STEPPER MOTOR DRIVER

Source: National Semiconductor

1



THE LMD18245 is a full-bridge power amplifier which incorporates all the circuit blocks required to drive and control current in a brushed type d.c. motor, or one phase of a bipolar stepper motor. The multi-technology process used to build the device combines CMOS control and protection circuitry with DMOS power switches on the same monolithic structure. The LMD18245 controls the motor current via a fixed off-time chopper technique.

An all-DMOS H-bridge power stage delivers continuous output currents up to 3 A (6 A peak) at supply voltage up to 55 V. The DMOS power switches feature low $R_{DS(on)}$ for high efficiency, and a diode intrinsic to the DMOS body structure eliminates the discrete diodes typically required to clamp bipolar power stages. An innovative current sensing method eliminates the power loss associated with a sense resistor in series with the motor. A four-bit digital-to-analogue converter (DAC) provides a digital path for controlling the motor current, and, by extension, simplifies implementation of full, half and microstep stepper motor drives. For higher resolution applications, an external DAC can be used. The block diagram of the LMD18245 is shown in **Fig. 1**.

The current sense amplifier

Many transistor cells in parallel make up the DMOS power switches. The current sense amplifier (**Fig. 2**) uses a small fraction of the cells of both upper switches to provide a unique, low-loss means for sensing the load current. In practice, each upper switch functions as a 1× sense device in parallel with a 4000× power device. The current amplifier forces the voltage at the source of the sense device to equal that at the source of the power device; thus, the devices share the total drain current in proportion to the 1:4000 cell ratio. Only the current flowing from drain to source, i.e., the forward current, registers at the output of the current sense amplifier. The latter therefore sources 250 µA per ampère of total forward current conducted by the upper two switches of the power bridge.

The sense current develops a potential across R_S that is proportional to the load current; for example, per ampère of load current, the sense current develops 1 V across a 4-kΩ resistor (the product of 250 µA per ampère and 4 kΩ). Since chopping the load current occurs as the voltage at CS OUT surpasses the threshold (the DAC output voltage), R_S sets the gain of the chopper amplifier; for example, a 2-kΩ resistor sets the gain at 2 A of load current per volt of the threshold (i.e., the reciprocal

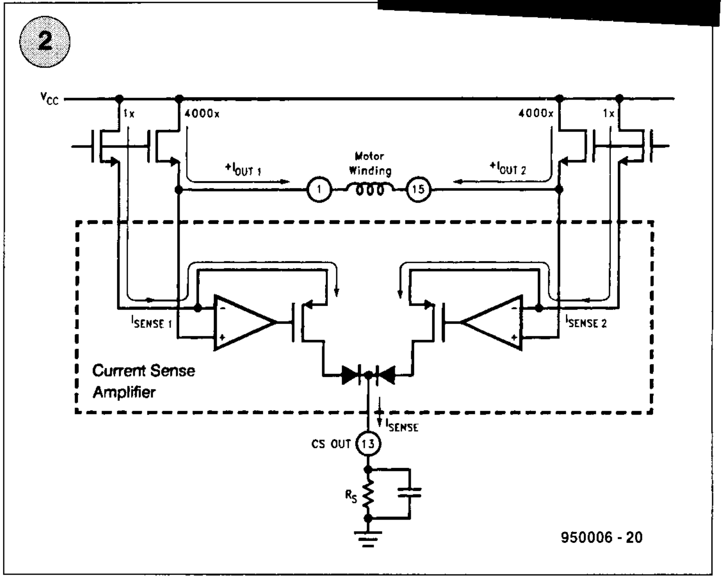
FEATURES

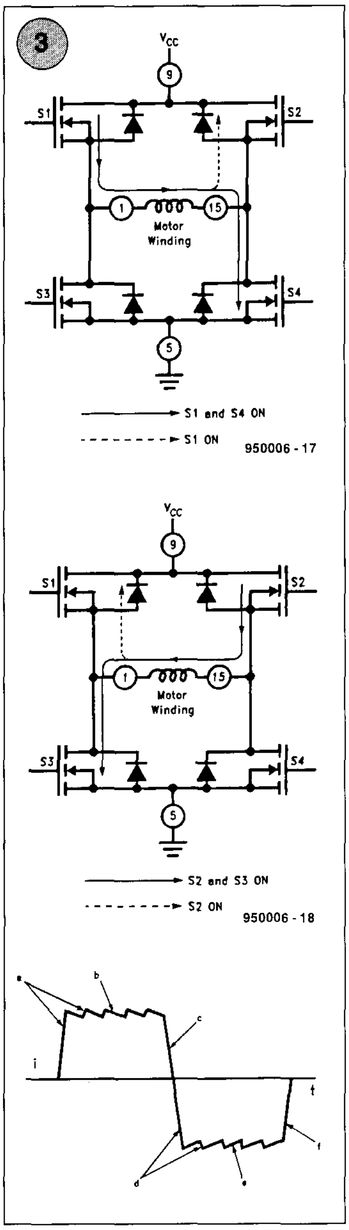
- » DMOS power stage rated at 55V and 3A continuous
- » Low $R_{DS(on)}$ of typically 0.3Ω per power switch
- » Internal clamp diodes
- » Low-loss current sensing method
- » Digital or analogue control of motor current
- » TTL and CMOS compatible inputs
- » Thermal shutdown (outputs off) at T_j=155°C
- » Overcurrent protection
- » No shoot-through currents
- » 15-lead TO-220 moulded power package

APPLICATIONS

- » Full, half and microstep stepper motor drives
- » Stepper motor and brushed d.c. motor servo drives
- » Automated factory, medical and office equipment

2





of the product of 250 µA per A and 2 kΩ). The specified operating voltage at the CS OUT pin is 0 to 5 V.

The digital-to-analogue converter (DAC)

The DAC sets the threshold for chopping at $V_{DAC\ REF} \times D/16$, where D is the decimal equivalent (0-15) of the binary number applied at the DAC inputs, M4 through M1. M4 is the most-significant bit (MSB). For applications that require higher resolution, an external DAC may be used to drive the DAC REF input. The specified operating voltage range at DAC REF is 0 to 5 V.

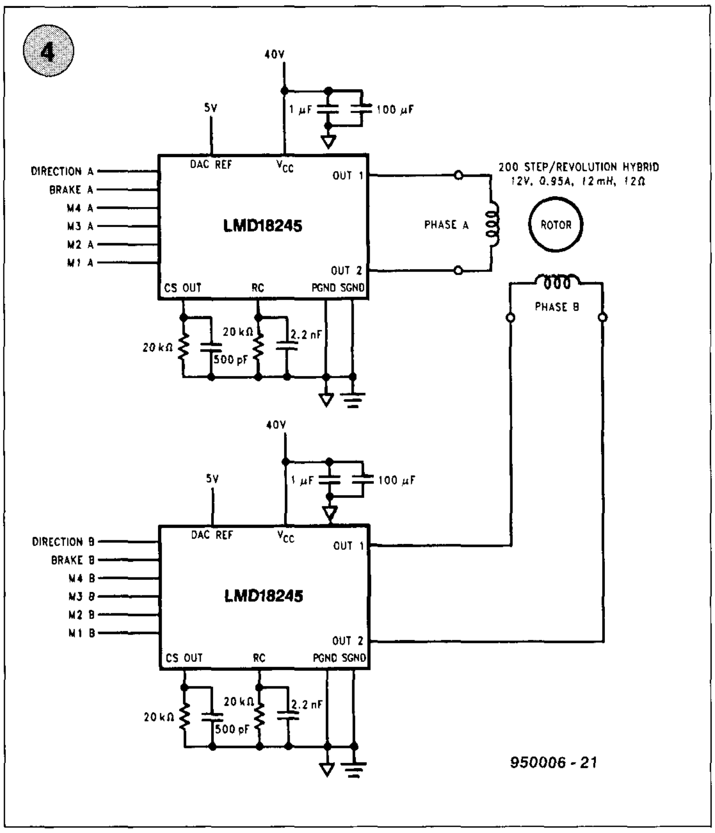
Comparator, monostable and winding current threshold for chopping

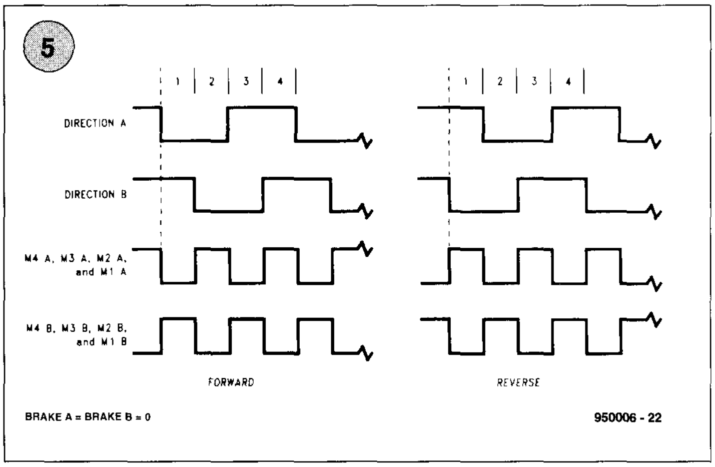
As the voltage at CS OUT surpasses that at the output of the DAC, the comparator triggers the monostable. This, once triggered, provides a timing pulse to the control logic. During the timing pulse, the power bridge shorts the motor winding, causing current in the winding to recirculate and decay slowly towards zero. A parallel *RC* network connected between RC (pin 3) and ground sets the timing pulse, or off-time, to about 1.1*RC* seconds.

Chopping of the winding current occurs as the voltage at CS OUT exceeds that at the output of the DAC; so chopping occurs at a winding current threshold of about

$$(V_{DAC\ REF} \times D/16) \div [(250 \times 10^{-6}) \times Rs] \text{ ampères.}$$

Apart from processing the MMV signal, the control logic also interprets the levels applied to the DIRECTION and BRAKE inputs of the IC. The H-bridge is capable of assuming different configurations, as illustrated in **Fig. 3**. Turning ON a source switch and a sink switch in opposite halves of the bridge forces the full supply voltage less the switch drops across the motor winding (a). While the bridge remains in this state, the winding current increases exponentially towards a limit dictated by the supply voltage, the switch drops, and the winding resistance. Subsequently turning OFF the sink switch causes a voltage transient that forward biases the body diode of the other source switch. The diode clamps the transient at one diode drop above the supply voltage, and provides an alternative current path. While the bridge remains in this state, it essentially shorts the winding, and the winding current recirculates and decays exponentially towards zero (b). This process is repeated until the DIRECTION signal changes. Both the switches and the body diodes then provide a decay path for the initial winding current, which rapidly drops to zero (c). Next, the control logic re-configures the H-bridge, so that the current flows through S2, the motor winding and S3. The motor current waveshape is then described by (d), (e) and (f) in the lower drawing.





Modes of operation

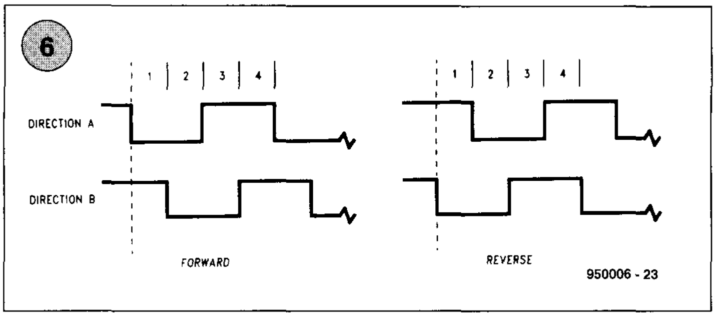
A typical application of two LMD18245s driving a stepper motor is shown in **Fig. 4**. The chopper off-time is set to about 48 µs by the 20-kΩ resistor and 2.2-nF capacitor connected between RC and ground. The chopper gain is set to about 200 mA per volt of the threshold by the 20-kΩ resistor at the CS OUT pin. Digital signals supplied by a microcontroller govern the thresholds for chopping, the directions of the winding currents, and, by extension, the drive type (full step, half step, etc.).

Full step drive

There are two types of full step drive. In one-phase drive (**Fig. 5**), the motor can be made to take full steps by *energizing windings A and B* in the sequence

A → B → A' → B' → A → ...

where A and B represent the currents in one direction through the respective windings, and A' and B', the reverse currents. The motor takes one full step each time one winding is de-energized and the other is energized. To make the motor reverse,



the above sequence must be reversed. That is achieved by swapping the levels of the DIRECTION signals.

Two-phase drive (**Fig. 6**) also results in full steps, and is described by the sequence

AB → A'B → A'B' → AB' → AB → ...

Because both windings are energized at all times, this sequence produces more torque than with one-phase drive. All DAC inputs are held permanently high.

Half-step drive without torque compensation

To make the motor take half steps (**Fig. 7**), windings A and B can be energized in the sequence

A → AB → B → A'B → A' → A'B' → B' → AB' → A → ...

It is important to note that although half stepping doubles the step resolution, changing the number of energized windings from two to one decreases torque by about 40%, resulting in significant torque ripple and possibly noisy operation.

Half-step drive with torque compensation

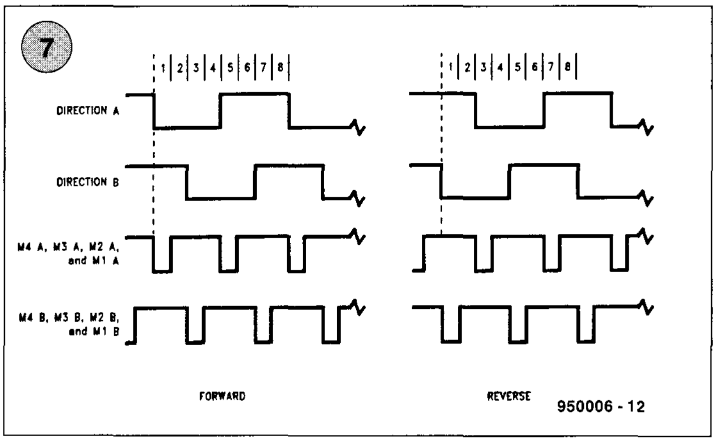
The above problem can be solved by torque compensation (**Fig. 8**). Essentially, the windings are then energized with sinusoidal currents. Controlling the winding currents in this fashion doubles the step resolution without the significant torque ripple of the prior drive technique. Along with the obvious advantage of increased step resolution, this microstepping reduces both full-step oscillations and resonances that occur as the motor and load combination is driven at its natural resonant frequency, or subharmonics thereof. When compared to full step drive, microstepping makes the motor run smoother and quieter. **Table 1** shows the phase angle, α, and the associated cosine values for winding A, and sine values for winding B, for each of the eight different half steps (each full 360° cycle comprises of four full steps).

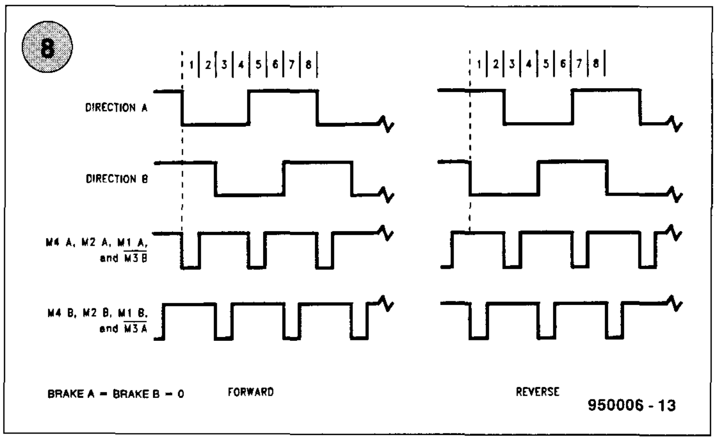
Quarter step drive with torque compensation

The quarter step drive mode only differs from the half-step mode in respect of the resolution. A 360° cycle is divided into 16 steps. Four microsteps then equal one full step. The relevant control data is shown in **Table 2**. (950006)

Source:

LMD18245 data sheet, National Semiconductor.




⑧
1
2
3
4
5
6
7
8
DIRECTION A
DIRECTION B
M4 A, M2 A, M1 A, and $\overline{\text{M3 B}}$
M4 B, M2 B, M1 B, and $\overline{\text{M3 A}}$
BRAKE A = BRAKE B = 0
FORWARD
REVERSE
950006 - 13

		α	cos α	DAC A	DIR A	sin α	DAC B	DIR B
⇐ Forward	Reverse ⇒	0	1	15	1	0	0	1
		45	0.707	11	1	0.707	11	1
		90	0	0	0	1	15	1
		135	0.707	11	0	0.707	11	1
		180	1	15	0	0	0	0
		225	0.707	11	0	0.707	11	0
		270	0	0	1	1	15	0
		315	0.707	11	1	0.707	11	0
		REPEAT						

Table 1. Lookup table for half-step drive with torque compensation. Note: 90° electrical/full step ÷ 2 microsteps/full step = 45° electrical/step.

	α	cos α	DAC A	DIR A	sin α	DAC B	DIR B
⇐ Forward Reverse ⇒	0	1	15	1	0	0	1
	22.5	0.924	14	1	0.383	6	1
	45	0.707	11	1	0.707	11	1
	67.5	0.383	6	1	0.924	14	1
	90	0	0	0	1	15	1
	112.5	0.383	6	0	0.924	14	1
	135	0.707	11	0	0.707	11	1
	157.5	0.924	14	0	0.383	6	1
	180	0	15	0	0	0	0
	202.5	0.924	14	0	0.383	6	0
	225	0.707	11	0	0.707	11	0
	247.5	0.383	6	0	0.924	14	0
	270	0	0	1	1	15	0
	292.5	0.383	6	1	0.924	14	0
	315	0.707	11	1	0.707	11	0
	337.5	0.924	14	1	0.383	6	0
	REPEAT						

Table 2. Winding currents and Lookup Table for quarter-step drive with torque compensation. Note: 90° electrical/full step ÷ 4 microsteps/full step = 22.5° electrical/microstep.

LMD18245 Electrical Characteristics

The following specifications apply for V_{CC} = +42V, unless otherwise stated. **Bold-face limits apply over the temperature range −40 °C ≤ T_J ≤ +125 °C**. All other limits apply for T_A = T_J = 25 °C.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Unit
I_{cc}	Quiescent current		DAC REF = 0V, V_{CC}= +20V		8	15	mA
POWER OUTPUT STAGE							
$R_{DS(on)}$	Switch ON resistance		I_{LOAD} = 3A		0.3	0.4	Ω
						0.6	Ω
			I_{LOAD} = 6 A		0.3	0.4	Ω
						0.6	Ω
V_{DIODE}	Body Diode Forward Voltage		I_{DIODE} = 3A		1.0	1.5	V
T_{rr}	Diode Reverse Recovery Time		I_{DIODE} = 1A		80		ns
Q_{rr}	Diode Reverse Receovery Charge		I_{DIODE} = 1A		40		nC
$t_{D(ON)}$	Output Turn ON Delay Time	Sourcing Outputs	I_{LOAD} = 3A		5		µs
		Sinking Outputs	I_{LOAD} = 3A		900		ns
$t_{D(OFF)}$	Output Turn OFF Delay Time	Sourcing Outputs	I_{LOAD} = 3A		600		ns
		Sinking Outputs	I_{LOAD} = 3A		400		ns
t_{ON}	Output Turn ON Switching Time	Sourcing Outputs	I_{LOAD} = 3A		40		µs
		Sinking Outputs	I_{LOAD} = 3A		1		µs
t_{OFF}	Output Turn OFF Switching Time	Sourcing Outputs	I_{LOAD} = 3A		200		ns
		Sinking Outputs	I_{LOAD} = 3A		80		ns
t_{pw}	Minimum Input Pulse Width	pins 10 and 11			2		µs
t_{DB}	Minimum Dead Band				40		ns
CURRENT SENSE AMPLIFIER							
	Current Sense Output		I_{LOAD} = 1A	200	250	300	µA
				175		**325**	µA
	Linearity Error		I_{LOAD}=0.5-3A		±6		%
	Current Sense Offset		I_{LOAD} = 0A		5	20	µA
DIGITAL-TO-ANALOG CONVERTER (DAC)							
	Resolution			**4**			Bits
	Monotonicity			**4**			Bits
	Total Unadjusted Error				0.125	0.25	LSB
						0.5	LSB
	Propagation Delay				50		ns
I_{REF}	DAC REF input current		DAC REF=+5V		−0.5	**±10**	µA
COMPARATOR AND MONOSTABLE							
	Comparator High Output Level				6.27		V
	Comparator Low Output Level				88		mV
	Comparator Output Current		Source		0.2		mA
			Sink		3.2		mA
t_{DELAY}	Monostable Turn OFF Delay				1.2	2.0	µs
PROTECTION AND PACKAGE THERMAL RESISTANCES							
	Undervoltage Lockout, V_{CC}			5		8	V
T_{JSD}	Shutdown Temperature, T_j				155		°C
Θ_{JC}	Package Thermal Resistance	Junction-to-Case			1.5		°C/W
Θ_{JA}	Package Thermal Resistance	Junction-to-Ambient			35		°C/W
LOGIC INPUTS							
V_{IL}	Low Level Input Voltage			**-0.1**		**0.8**	V
V_{IH}	High Level Input Voltage			**2**		**12**	V
I_{IN}	Input Current		V_{IN}=0V or 12V			**±10**	µA

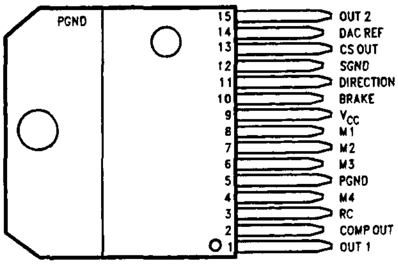
Absolute Maximum Ratings

d.c voltage at OUT 1, OUT 2 and VCC	+60 V
d.c. voltage at COMP OUT, RC, Mx, BRAKE, DIRECTION, CS OUT and DAC REF	+12V
d.c voltage PGND to SGND	±400mV
Continuous Load Current	3A
Peak Load Current	6A
Junction Temperature	+150°C
Power dissipation, T_A = 25 °C, infinite heatsink	25W
Power dissipation, T_A = 25 °C, *free air*	3.5W
ESD susceptibility	1500V
Storage temperature range	−65 to +150°C

Operating Conditions

Temperature range	−40 to +125°C
Supply Voltage Range	+12 V to +55V
CS OUT Voltage Range	0V to +5V
DAC REF Voltage Range	0V to +5V
MMV pulse width	10µs to 100 ms

Pinout Descriptions



950006 - 19

Pin 1, OUT1: Output node of the first half H-bridge

Pin 2, COMP OUT: Output of the comparator. If the voltage at CS OUT exceeds that provided by the DAC, the comparator triggers the monostable.

Pin 3, RC: Monostable timing node. A parallel resistor-capacitor network connected between this node and ground sets the monostable timing pulse at about 1.1 RC seconds.

Pin 5, PGND: Ground return node of the power bridge. Bond wires (internal) connect PGND to the tab of the TO-220 package.

Pins 4 and 6 through 8, M4 through M1: Digital inputs of the DAC. These inputs make up a four-bit binary number with M4 as the most significant bit or MSB. The DAC provides an analogue voltage directly proportional to the binary number applied at M4 through M1.

Pin 9, Vcc: Power supply node.

Pin 10, BRAKE: Brake logic input. Pulling the BRAKE input logic-high activates both sourcing switches of the power bridge, effectively shorting the load. Shorting the load in this manner forces the load current to recirculate and decay to zero.

Pin 11, DIRECTION: Direction logic input. The logic level at this input dictates the direction of the current flow in the load.

Pin 12, SGND: Ground return node of all signal level circuits.

Pin 13, CS OUT: Output of the current sense amplifier. The current sense amplifier sources 250µA (typical) per ampere of total forward *current conducted by the upper two switches* of the power bridge.

Pin 14: DAC REF: Voltage reference input of the DAC. The DAC provides an analogue voltage equal to $V_{DAC\ REF}$ x D/16, where D is the decimal equivalent (0-15) of the binary number applied to M4 through M1.

Pin 15, OUT2: Output node of the second half H-bridge.

LONG-LIFE NIGHT LIGHT

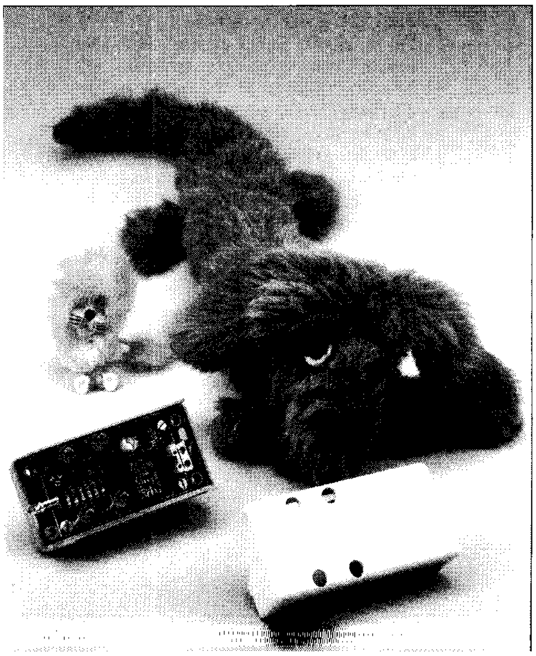
This article describes an automatically operating night light with two remarkable features. First of all, a light-operated switch turns the lamp on and off automatically depending on ambient light intensity. Secondly, the night light never requires a bulb to be exchanged, simply because there is no bulb inside.

Design by H. Bonekamp

NIGHT lights are often the subject of debates. Either you need one to be able to sleep, or you can not sleep when there is one around in the bedroom. In particular, children often appear to feel much more at ease if a night light is present in their bedroom. The light has a reassuring effect because it appears to function as an orientation aid during periods of light sleep and waking.

Commercially available night lights come in two kinds. The cheap ones have a neon lamp and are on as long as they are plugged into the mains socket. The more expensive types have a small bulb inside, and feature a light-sensitive switch which turns on the light when it gets dark.

Both types have their own advantages and disadvantages. The neon lights are inexpensive and use little power. On the down side, they do waste energy by remaining on all the time, and often provide insufficient light. The automatic types provide much more light at the cost of a higher current consumption. They also require the (fairly expensive) bulb to be exchanged from time to time. The ideal compromise between the two types would be a version having a light/dark sensor control and an economical lamp with the same life expectancy as a neon light, but a higher light output.



Although these requirements may appear contradictory, the design presented here offers the best of both worlds by exchanging the bulb for a couple of super-luminosity LEDs.

Profile

Before discussing the design in greater detail, it may be worthwhile to state our *desiderata*. To start with, a reliably operating light/dark switch with adjustable sensitivity is needed to make sure that the on/off switching behaviour is predicable. Furthermore, the circuit should have a reasonable degree of hysteresis to prevent oscillation around the threshold level. Next, the switch should be immune against brief variations of the ambient light intensity. A further wish is to be able to determine the amount of light produced by the night light by fitting one or several 'super-LEDs', without changing the brightness of individual LEDs.

On a different tack, there is, of course, the safety aspect to consider. The night light being used in a children's bedroom, it must be absolutely safe, with complete electrical insulation between the mains voltage and parts which can be touched from the outside. Finally, the night light should be a compact unit which can be plugged straight into a mains socket. No wires, no external controls.

Four transistors

All requirements mentioned so far are satisfied by a relatively simple circuit. Looking at the circuit diagram in **Fig. 1**, there are only four transistors, four LEDs and a handful of passive parts.

LEDs D_2 through D_5 at the right-hand side of the diagram supply the light. So-called super-red LEDs with a diameter of 8 mm are used here. These devices come in a diffused-light enclosure with an aperture angle of about 120°, and supply 'soft' light with an intensity of about 500 mCd at 20 mA. Not all of the LEDs shown in the circuit diagram have to be fitted — depending on the desired light intensity, one, two, three or four super LEDs may be fitted without having to change anything in the circuit. This is by virtue of a current source which powers the LEDs. The current source consists of T_4 and surrounding components, of which D_6 and D_7 have a crucial function because they keep the base of T_4 at a constant voltage of about 1.2 V. The voltage across R_8 is, therefore, 0.6 V, which causes a constant emitter current (and collector current) of about 22 mA because R_8 has a value of 27 Ω.

The constant current source is switched on and off by T_3, which forms the final stage of the light-sensitive switch. This also comprises transistors T_2 and T_1. The latter is a phototransistor which functions as a sensor for ambient light. The more light it detects, the harder it conducts. Depending on the setting of preset P_1, a certain amount of ambient light seen by T_1 causes T_2 to be driven. This, in turn, causes the constant current source to be turned on via T_3, so that the LEDs light at a constant intensity.

Positive feedback via resistor R4 gives the circuit just the right amount of hysteresis. As long as the current source operates, a part of the positive voltage at the collector of T_3 (approx. 1.2 V) is fed to the base of T_2 via resistor R_4. Because T_4 is a p-n-p type, the additional voltage pinches the device off a little more, so that the threshold to be overcome by the photocurrent through T_1 is raised a little.

In case T_1 detects an amount of light which causes sufficient conduction, the feedback via R_4 has just the opposite effect. T_2 and T_3 then start to conduct, and the voltage at the collector of T_3 drops considerably. This low level is also fed to the base of T_2 via R_4, so that the transistor conducts a little harder. Consequently, a relatively large decrease in photocurrent through T_1 is needed to make the switch toggle again. The voltage feedback via R_4 creates a difference between the 'on' and 'off' levels which is sufficiently large to prevent oscillation around the threshold level.

Capacitor C_1 has been added to prevent the operation of the circuit from being disturbed by brief variations of the ambient light intensity detected by T_1. Although the capacitor is not too large, it does make the voltage variations at the base of T_1 much slower than those at the wiper of P_1.

The night light is powered by a classic supply consisting of a transformer, a bridge rectifier and a reservoir electrolytic. Because the circuit draws very little current, the transformer used is a

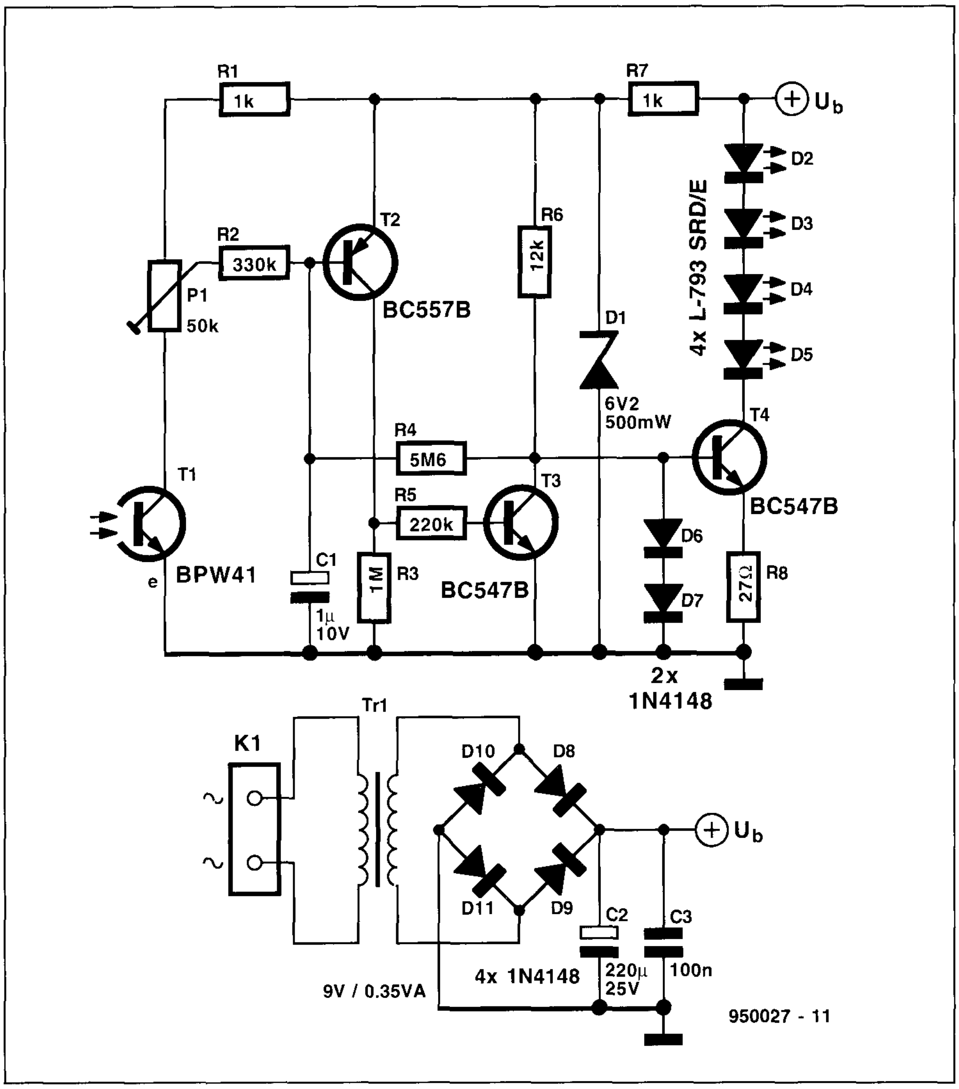


Fig. 1. The circuit may be divided into a light-sensitive switch (T_1, T_2 and T_3) and a constant-current source (T_4) which powers a number of diffused-light super-LEDs.

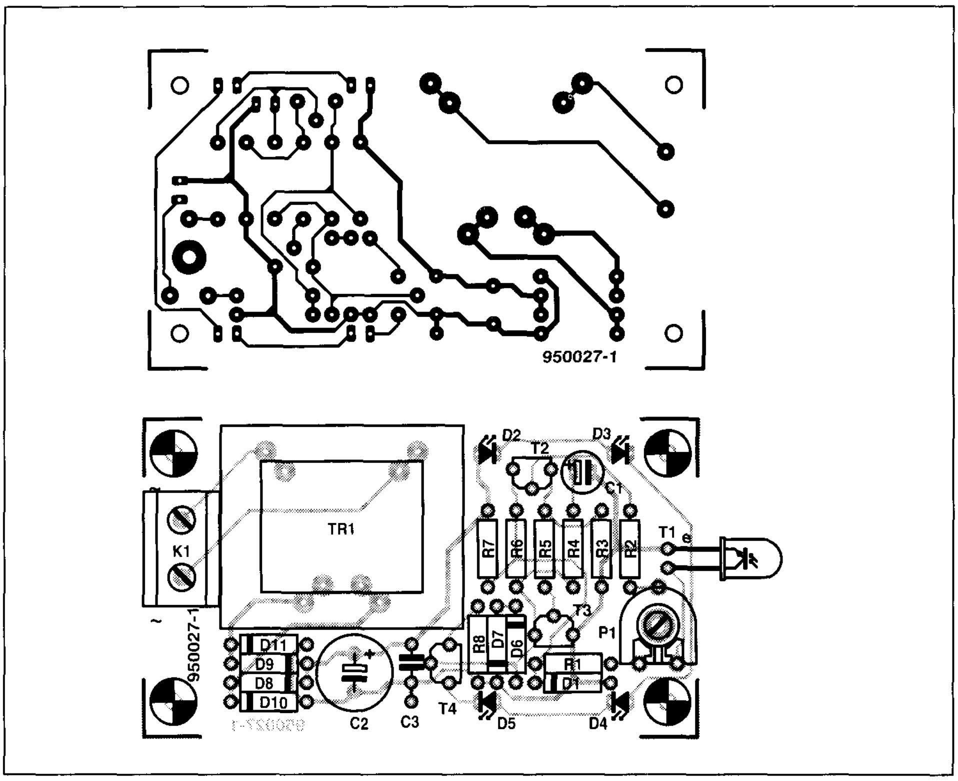


Fig. 2. PCB design (board not available ready-made through the Readers Services).

COMPONENTS LIST

Resistors:
R_1,R_7 = 1kΩ
R_2 = 330kΩ
R_3 = 1MΩ
R_4 = 5MΩ6
R_5 = 220kΩ
R_6 = 12kΩ
R_8 = 27Ω
P_1 = 50kΩ

Capacitors:
C_1 = 1µF 10V radial
C_2 = 220µF 25V radial
C_3 = 100nF

Semiconductors:
D_1 = 6V2 500 mW zener diode
D_2-D_5 = L-793 SRD/E (Kingbright*)
D_6,D_7-D_{11} = 1N4148
T_1 = BPW41 (Siemens)
T_2 = BC557B
T_3,T_4 = BC547B

Miscellaneous:
K_1 = PCB terminal block, pitch 7.5 mm.
Tr_1 = PCB mount mains transformer, sec. 9 V/0.35 VA (Hahn, or Monacor type VTR1109, Velleman type 1090018M or Block type VR1109).
Case, e.g. power supply case with moulded mains plug (approx. size 100x50x40 mm) (Maplin).
PCB not available ready-made through the Readers Services.

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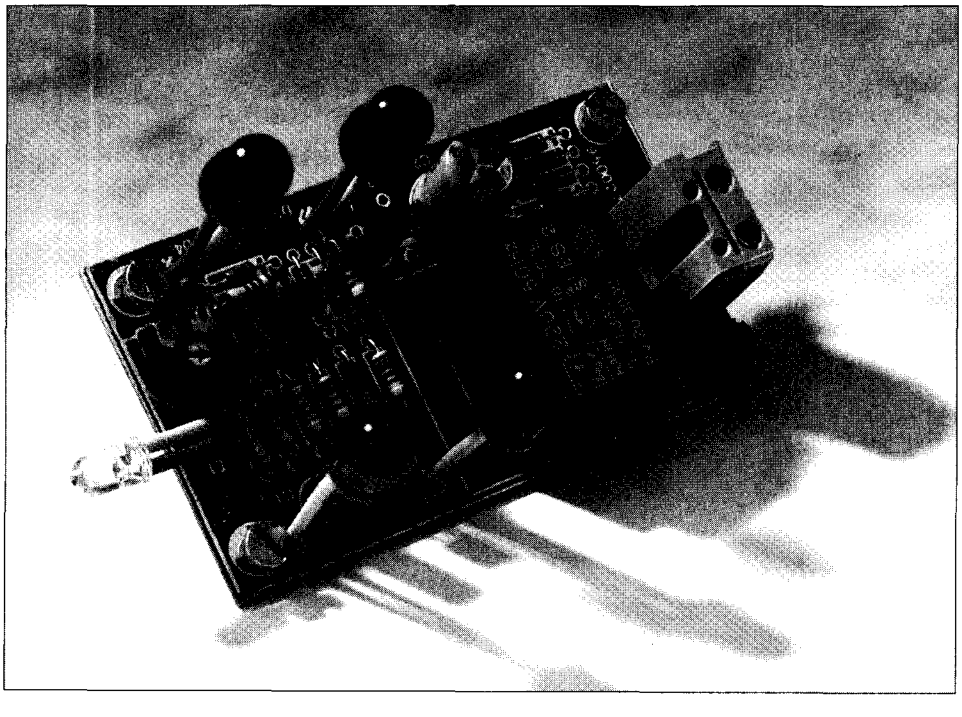
pretty small type rated at 9 V, 0.35 VA only. For the same reason, low-current diodes type 1N4148 are used as rectifiers. To keep out the effects of voltage fluctuations, the supply voltage for the electronic switch is separated from the current source, and stabilized at 6.2 V with the aid of a simple zener diode, D_1.

Construction

The printed circuit board designed for the night light is shown in **Fig. 2**. Unfortunately, this board is not available ready-made through the Readers Services, so you have to make it yourself, or have it made for you. Building up the board is not expected to cause problems, the parts being few and common. The design of the board allows a number of transformers to be used, while up to four LEDs may be mounted. LEDs not fitted must be replaced by a wire link.



There are two important points about building the circuit into a case. First, T_1 should not be allowed to 'see' the light produced by the LEDs, and, secondly, an electrically safe enclosure should be used. The first point is easy to accomplish by fitting the phototransistor such that it looks upwards, while the LEDs point straight ahead.

Safety need not be a problem if you use a so-called power supply case with a moulded mains plug. To make the night light 'child-proof', consider applying lacquer over the screw heads. Before closing the case, however, the sensitivity preset, P_1, has to be adjusted. In most cases, it is best to wait until you think it is sufficiently dark, and then adjust P_1 until the light is just switched on. (950027)

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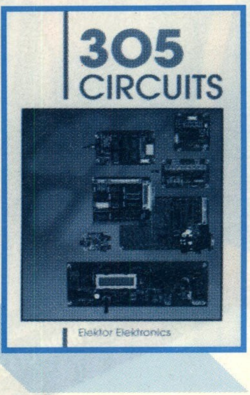

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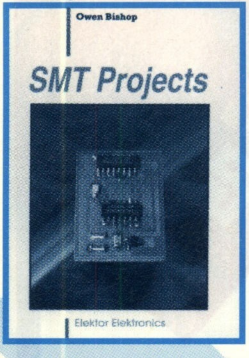

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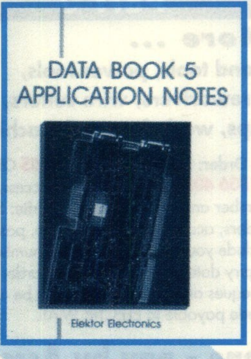

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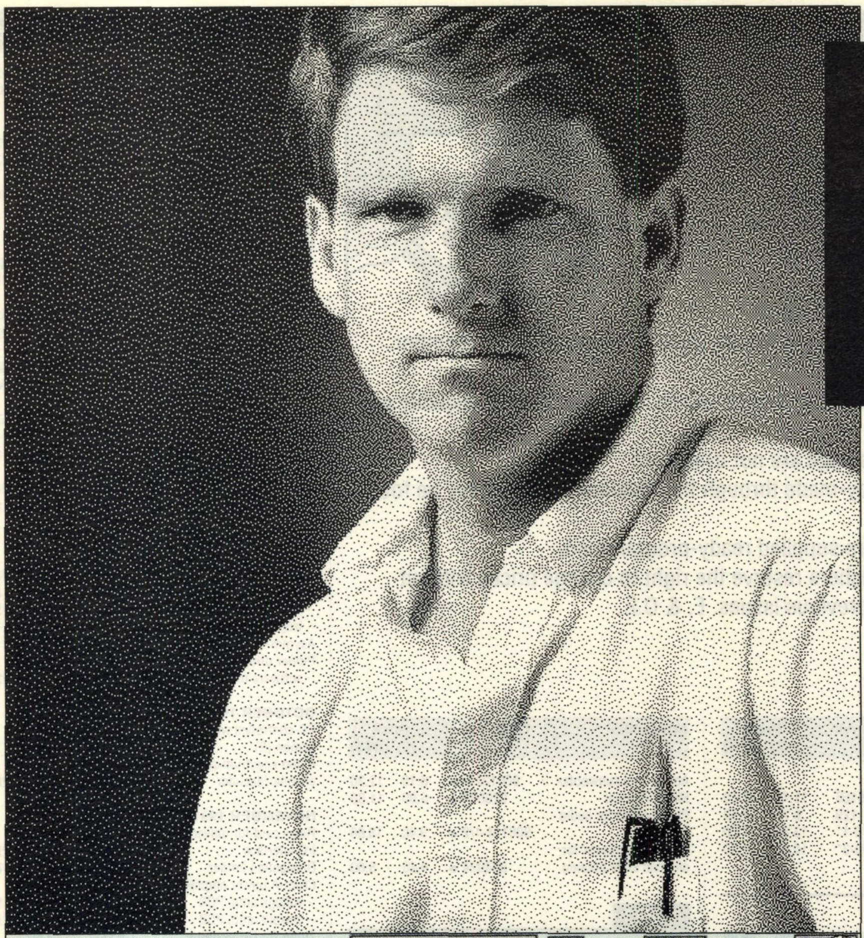

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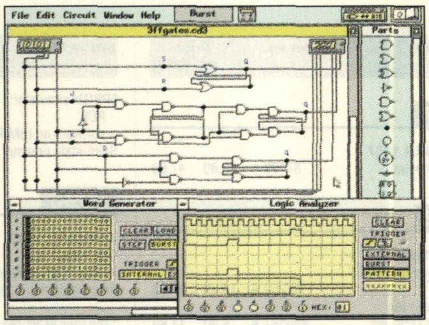

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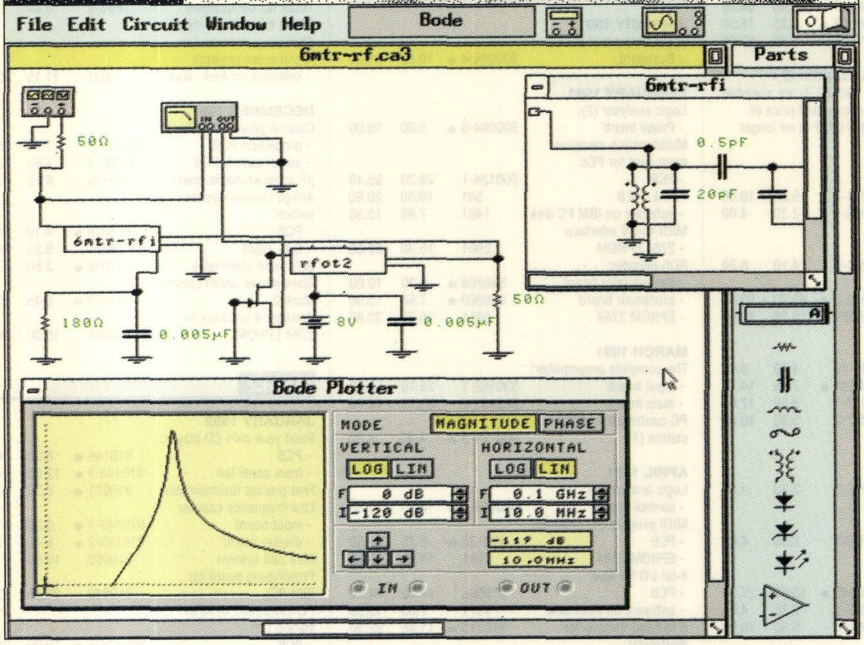

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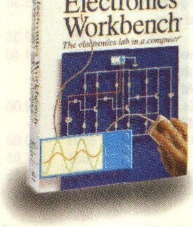

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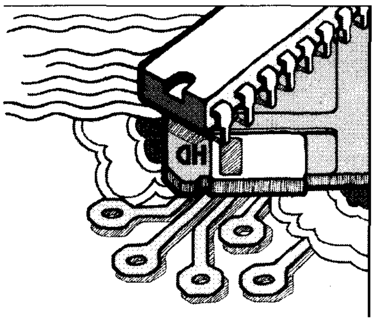
MARCH 1995



Ready-made printed-circuit boards (PCBs), self-adhesive front panel foils, ROMs, EPROMs, PALs, GALs, microcontrollers and diskettes for projects which have appeared in *Elektor Electronics* may be ordered through our Readers Services using the order form printed every month opposite the Readers Services page. This two-page overview of currently available products is regularly updated and appears in the March, June, September and December issues of *Elektor Electronics*.

» Items marked with a dot (•) following the product number are in limited supply only, and their availability can not be guaranteed by the time your order is received.

» Items not listed here or on this month's Readers Services page are not available.

» The artwork for making PCBs which are not available ready-made through the Readers Services may be found in the relevant article (from March 1990 onwards).

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» Prices and item descriptions subject to change. The publishers reserve the right to change prices without prior notification. Prices shown here supersede those in previous issues. E. & O.E.

Article title	Order no.	Price	
		(£)	(US$)
1987			
NOVEMBER 1987			
BASIC computer	87192	23.80	47.60
1988			
MARCH 1988			
Computer-controlled slide fader	87259 •	18.80	37.60
Signal divider for satellite TV receivers	880067 •	5.90	11.80
APRIL 1988			
Fuzz unit for guitars	87255 •	7.65	15.30
JULY/AUGUST 1988			
Frequency read-out for SW receivers	880039 •	21.60	43.20
OCTOBER 1988			
Peripheral modules for BASIC computer	880159 •	5.90	11.80
NOVEMBER 1988			
Bus interface for hi-res LCD screens	880074 •	19.70	39.40
LFA-150 — a fast	880092-1 •	9.95	19.90
power amplifier	880092-2 •	9.20	18.40
DECEMBER 1988			
LFA-150 — a fast	880092-3 •	7.50	15.00
power amplifier	880092-4 •	7.60	15.20
CVBS-to-TTL adaptor	880098 •	5.70	11.40
Autonomous I/O controller	880184 •	18.00	36.00
1989			
JANUARY 1989			
Fax interface for Atari ST and Archimedes	880109	8.65	17.30
Low-budget capacitance meter	UPBS-1	2.30	4.60
FEBRUARY 1989			
Digital Model Train	87291-1	4.95	9.90
VHF receiver	886127	8.75	17.50
APRIL 1989			
Digital Model Train	87291-2/3	5.05	10.10
Function generator	UPBS-1	2.30	4.60
Multi-point IR control	890019-1	4.05	8.10
	890019-2	4.75	9.50
MAY 1989			
Digital Model Train (4)	87291-4	6.15	12.30
DTMF system decoder	890060	7.65	15.30
Sine-wave converter	UPBS-1	2.30	4.60
JULY/AUGUST 1989			
Function generator	UPBS-1	2.30	4.60
SEPTEMBER 1989			
Digital Model Train	87291-6	7.85	15.70
Resonance meter	886071	4.60	9.20
NOVEMBER 1989			
Digital Model Train (8)	87291-5	51.10	102.20
DECEMBER 1989			
Digital Model Train	87291-7	10.30	20.60
EPROM simulator:			
- PCB	890166	11.75	23.50
- software on IBM PC disk	129	6.75	13.50
Solid-state preamp	890170-1*	13.80	27.60
	890170-3*	10.60	21.20
1990			
JANUARY 1990			
Video mixer (1)	87304-1	32.00	64.00
Mini EPROM programmer	890164 •	8.25	16.50
All solid-state preamplifier	890170-2*	18.50	37.00

*The four PCBs required for the preamplifier (2 × 890170-1; 1× 890170-2 and 1× 890170-3) are available as a package, ref. 890170-9, at a discounted price of £48.15 (US$96.30). Front panel 890170-F is no longer available.

Article title	Order no.	Price	
		(£)	(US$)
FEBRUARY 1990			
Digital Model Train (11)	87291-8	5.30	10.60
Reflex MW AM receiver	UPBS-1	2.30	4.60
MARCH 1990			
Digital model train (12)	87291-9	4.10	8.20
Video mixer (3):			
- PCB	87304-3 •	41.70	83.40
- EPROM 27128	5921	15.30	30.60
APRIL 1990			
Digital model train (13)	87291-10	4.70	9.40
Q meter	900031 •	7.05	14.10
RS-232 splitter	*900017-1*	*8.50*	*17.00*
	900017-2	5.30	10.60
MAY 1990			
Acoustic temperature monitor	UPBS-1	2.30	4.60
JUNE 1990			
Power zener diode	UPBS-1	2.30	4.60
JULY/AUGUST 1990			
Compact 10A power supply	900045 •	13.50	27.00
Intermediate projects	UPBS-1	2.30	4.60
Mini FM transmitter*	896118	5.00	10.00
Sound demodulator for satellite TV receivers	900057 •	4.40	8.80
Audio power indicator	904004 •	4.40	8.80
Four-monitor driver for PCs	904067 •	6.15	12.30

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		(£)	(US$)
SEPTEMBER 1990			
Infra-red remote control	904085/86	7.95	15.90
OCTOBER 1990			
µP-controlled telephone exchange:			
- PCB	900081 •	21.15	42.30
- EPROM 27128	5941	15.30	30.60
S-VHS/CVBS-to-RGB converter	900055 •	14.40	28.80
NOVEMBER 1990			
400-watt laboratory PSU	900082 •	12.95	25.90
Medium-power audio amplifier	900098	10.60	21.20
Programmer for the 8751			
- PCB	900100	8.25	16.50
- µC 87C51	7061	46.40	92.80
- software on IBM PC disk	1471	7.65	15.30
DECEMBER 1990			
Active mini subwoofer	*900122-2 •*	*6.15*	*12.30*
Milliohmmeter	910004 •	5.90	11.80
Phase check for audio systems	900114-1/2 •	9.40	18.80
Signal suppressor for all-solid state preamp	904024 •	4.40	8.80
1991			
JANUARY 1991			
Logic analyser (1):			
- Busboard	900094-4 •	10.60	21.20
FEBRUARY 1991			
Logic analyser (2):			
- Probe board	900094-3 •	5.00	10.00
Multifunction measurement card for PCs:			
- PCB	900124-1	28.20	56.40
- PAL 16L8	561	10.30	20.60
- software on IBM PC disk	1461	7.65	15.30
MIDI-to-CV interface:			
- 2764 EPROM	5981	15.30	30.60
RDS decoder:			
- demodulator board	880209 •	5.30	10.60
- processor board	900060 •	7.65	15.30
- EPROM 2764	5951	15.30	30.60
MARCH 1991			
The complete preamplifier:			
- input board	890169-1	26.10	52.20
- main board	*890169-2*	*39.35*	*78.70*
PC-controlled weather station (1)	900124-3 •	4.40	8.80
APRIL 1991			
Logic analyser (3):			
- control board	900094-5 •	18.50	37.00
MIDI programme changer:			
- PCB	900138 •	6.75	13.50
- EPROM 2764	5961	15.30	30.60
8-bit I/O for Atari:			
- PCB	910005	12.35	24.70
- software on Atari disk	1571	7.65	15.30
6-m band transverter	910010 •	11.45	22.90
Wattmeter:			
- meter board	910011-1 •	6.45	12.90
- display board	910011-2 •	4.10	8.20
Tektronix/Intel file converter:			
- software on IBM PC disk	1581	7.65	15.30
Moving-coil (MC) preamplifier	910016 •	10.60	21.20
Dimmer for halogen lights:			
- transmitter board	910032-1 •	4.10	8.20
- receiver board	910032-2 •	4.40	8.80
MAY 1991			
80C32/8052 Computer	910042	12.05	24.10
Battery tester	906056	4.10	8.20
Universal I/O interface for IBM PCs	910046	10.85	21.70
JUNE 1991			
Universal battery charger	*900134*	*9.40*	*18.80*
Logic analyser - 4:			
- power supply board	900094-7 •	8.80	17.60
- Atari interface board	900094-6 •	12.65	25.30
- IBM interface board	900094-1 •	14.40	28.80
- PAL 16L8 for IBM i/face	5971	8.25	16.50
Digital phase meter (set of 3 PCBs)	910045-1/2/3 •	26.15	52.30
Light transceiver	UPBS-1	2.30	4.60
Variable AC PSU:			
- PCB	900104 •	6.15	12.30
- front panel foil	900104-F	16.45	32.90
Light switch with TV IR r/c	910048	5.60	11.20
Real-time clock for Atari ST:			
- PCB	910006	6.15	12.30
- software on IBM PC disk	1621	7.65	15.30
Stepper motor board -1:			
- PAL 16L8	6011	8.25	16.50
JULY/AUGUST 1991			
Multifunction I/O for PCs:			
-PCB	910029	24.40	48.80
- PAL 16L8	5991	8.25	16.50
B/W video digitizer:			
- PCB	910053 •	22.60	45.20
- software on Arch. disk	1591	11.15	22.30
Logic analyser - 5:			
- IBM PC disk + LA-GAL	1491	19.40	38.80
- Atari disk + LA-GAL	1501	19.40	38.80
Stepper motor board - 2:			
- power driver board	910054-2	28.50	57.00
LED voltmeter	914005 •	5.60	11.20
Wien bridge	914007 •	4.10	8.20
Angled bus extension card for PCs	914030 •	12.05	24.10
Sync separator	914077 •	4.40	8.80
SEPTEMBER 1991			
Timecode interface for slide control:			
- main board	910055	24.40	48.80
- display board	87291-9a	4.10	8.20
- software on IBM PC disk	1611	7.65	15.30
- front panel foil	910055-F	8.80	17.60
Asymm-symm converter	910072	5.60	11.20
Plotter driver:			
- software on IBM PC disk	1541	11.15	22.30
OCTOBER 1991			
PC-controlled weather station (2)	900124-2 •	3.80	7.60
Audio spectrum shift encoder/decoder	*910105 •*	*10.35*	*20.70*
NOVEMBER 1991			
Relay card for universal I/O interface	910038 •	12.95	25.90
Dissipation limiter	910071 •	4.40	8.80
Class-A power amplifier (1):			
- voltage amp. PCB	880092-1	9.95	19.90
- current amp. PCB	880092-2	9.05	18.10
Timer for CH systems	UPBS-2	3.80	7.60
24-bit full-colour video digitizer (extension for Archimedes project):			
- software on Arch. disk	1631	11.15	22.30
DECEMBER 1991			
Class-A power amplifier (2):			
- protection PCB	880092-3	7.50	15.00
- power supply PCB	880092-4	7.60	15.20
µP programmable filters	910125	6.75	13.50
Amiga mouse/joystick switch:			
- PCB	914078 •	4.10	8.20
- GAL 16V8	6001	8.25	16.50
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Slave mains on/off control Mark-2	914072 •	6.45	12.90
Connect-4 software in 2764 EPROM	6081	15.30	30.60
1992			
JANUARY 1992			
Build your own CD player:			
- PCB	910146 •	8.25	16.50
- front panel foil	910146-F •	12.05	24.10
Fast precise thermometer	910081 •	8.50	17.00
Low-frequency counter			
- input board	910149-1 •	5.00	10.00
- display board	910149-2 •	6.45	12.90
Mini Z80 system	910060	10.60	21.20
Prototyping board for IBM PCs	910049	21.15	42.30
PC-controlled weather station (3):			
- PCB	900124-5 •	10.00	20.00
- software on IBM PC disk (supersedes 1551 and 1561)	1641	7.65	15.30
FEBRUARY 1992			
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Switch-mode power supply	920001	4.40	8.80
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- EMON51 EPROM + course disk for IBM PCs (1661)	6061	20.00	40.00
- EMON51 EPROM + course disk for Atari (1681)	6091	20.00	40.00
- course disk for IBM PCs	1661	7.65	15.30
- course disk for Atari	1681	7.65	15.30
MARCH 1992			
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- front panel foil	920012-F	11.45	22.90
8751 emulator	920019	12.05	24.10
- EPROM 27C64 + IBM disk	6051	29.40	58.80
A-D/D-A and I/O for I^{2}C bus:			
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- software on IBM PC disk	1821	7.65	15.30
AF drive indicator	920016	5.60	11.20

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Centronics line booster	910133 ●	5.90	11.80
FM tuner (tuner board)	920005	21.15	42.30
MIDI optical link	920014	6.15	12.30
APRIL 1992			
80C32 SBC extension	910109	13.50	27.00
2-metre FM receiver	910134	10.30	20.60
Comb generator	920003	8.50	17.00
AD232 converter:			
- PCB	920010	12.35	24.70
- software on IBM PC disk	1691	7.65	15.30
Automatic NiCd charger	UPBS-1	2.30	4.60
LCD for L-C meter	920018	4.70	9.40
Milli-ohm meter adaptor	920020	4.40	8.80
May 1992			
1.3-GHz prescaler	914059	5.00	10.00
Compact mains supply	920021	7.35	14.70
FM tuner - 3 (PSU)	920005-2	8.80	17.60
GAL *programmer:*			
- PCB	920030	11.15	22.30
- software: see June 1993			
NICAM decoder:			
- PCB	920035	15.00	30.00
- front panel foil	920035-F	8.25	16.50
JUNE 1992			
I^{2}C display	920004	4.70	9.40
FM tuner - 4:			
- mode control board	920005-3	5.60	11.20
- *synthesizer board*	*920005-5*	*10.85*	*21.70*
Guitar tuner:			
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- front panel foil	920033-F	8.80	17.60
Multi-purpose Z80 card	920002	20.25	40.50
- GAL set (2x16V8)	6111	11.15	22.30
- BIOS EPROM 27128	6121	15.30	30.60
- software on IBM PC disk	1711	7.65	15.30
4MB printer buffer:			
- front panel foil	910110-F ●	11.45	22.90
- EPROM 27C64	6041	15.30	30.60
JULY 1992			
12VDC to 240VAC inverter			
- main board	920039-1	11.15	22.30
- power board	920039-2	6.45	12.90
- front panel foil	920038-F	16.15	32.30
Audio DAC - 1	920063-1	8.50	17.00
Optocard for universal PC I/O bus	910040 ●	12.95	25.90
FM tuner - 5:			
- *keyboard/display board*	920005-4	14.40	28.80
- S-meter board	920005-6	3.80	7.60
- EPROM 27C256	6101	15.30	30.60
- front panel foil	920005-F	13.20	26.40
RS232 quick tester	920037	5.00	10.00
Water pump control for solar power system	924007	7.35	14.70
Simple power supply	924024	5.00	10.00
Wideband active telescopic antenna	924102	3.25	6.50
SEPTEMBER 1992			
EPROM emulator - II:			
- PCB	910082	10.00	20.00
- software on IBM PC disk	129	6.75	13.50
Audio DAC - 2	920063-2	18.80	37.60
OCTOBER 1992			
Audio DAC - 3:			
- PCB	920063-3	26.45	52.90
- front panel foil	920063-F	10.00	20.00
Mains sequencer	920013	17.35	34.70
Wideband active antenna	924101	3.25	6.50
RDS demodulator	880209 ●	5.30	10.60
Pascal routines for Multi-function Measurement Card for PCs: software on disk	1751	9.70	19.40
NOVEMBER 1992			
Printer sharing unit	920011	14.70	29.40
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Low-power TTL-to-RS232 interface	920127	3.55	7.10
DECEMBER 1992			
Digital audio/visual system:			
- PCB + EPROM (6171)	920022-C	34.10	68.20
- EPROM 27C256	6171	10.30	20.60
- panel foil dissolve unit	920022-F1	10.00	20.00
- panel foil remote control	920022-F2	19.40	38.80
- panel foil main unit	920022-F3	28.80	57.60
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- *PCB + EPROM (6141)*	*920095-C*	*29.40*	*58.80*
- EPROM 27C256	6141	11.45	22.90
- front panel foil	920095-F	13.80	27.60
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	920135-2	7.95	15.90
Peak-delta NiCd charger	920147	4.10	8.20
IDC-to-boxheader adaptor	924049	6.45	12.90
Mini keyboard for Z80	924047	12.35	24.70
80C552 µP system	924071	20.00	40.00
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Speech/sound memory:			
- software on IBM PC disk	1771	7.65	15.30
1993			
JANUARY 1993			
PAL test pattern generator:			
- PCB + GAL (6211)	920129-C	15.30	30.60
- GAL 20V8	6211	9.40	18.80
Multi-core cable tester			
- matrix board	926079	17.05	34.10
- slave unit	926084	6.20	12.40
- master unit	926085	8.25	16.50
FEBRUARY 1993			
Digital audio/visual system (4):			
- software package, EPROM, GALs and IBM PC disk	6181	30.50	61.00
U2400B NiCd battery charger:			
- PCB	920098	8.75	17.50
- front panel foil	920098-F	8.75	17.50
Digital-audio enhancer	920169	14.25	28.50
I^{2}C opto/relay card:			
- PCB	930004	11.00	22.00
- software on IBM PC disk	1821	7.65	15.30
Watt-hour meter:			
- PCBs -1 and -2, and EPROM (6241)	920148-C	37.25	74.50
- EPROM 27256	6241	10.00	20.00
MARCH 1993			
Linear sound pressure meter	930006	7.00	14.00
Electrically isolated RS232 interface	920138	10.25	20.50
TV test pattern generator for 8032 SBC:			
- EPROM 27256	6151	15.30	30.60
APRIL 1993			
Audio power meter	*930018*	*10.25*	*20.50*
Video digitizer for PCs:			
- PCB + disk (1831)	930007-C	37.00	74.00
- Software on IBM PC disk	1831	14.50	29.00
Infrared receiver for 80C32 single-board computer:			
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- software on IBM PC disk, also for DTMF decoder	1791	7.50	15.00
4MB printer buffer card:			
- PCB	920009	27.50	55.00
- EPROM 27C64	6041	15.30	30.60
- front panel foil	920009-F	8.25	16.50
MAY 1993			
FM stereo signal generator	920155	23.00	46.00
VHF/UHF receiver	926001	19.00	38.00
Philips preamplifier:			
- PCB	930003	7.50	15.00
- software on IBM PC disk	1861	8.50	17.00
Workbench PSU:			
- main PCB	930033	21.50	43.00
- display PCB	920075-1	4.70	9.40
- front panel foil	930033-F	17.00	34.00
JUNE 1993			
Spectrum VU meter	920151	13.00	26.00
GAL programmer upgrade:			
- PCB	930060	4.50	9.00
- software on IBM PC disks	1701	11.15	22.30
- idem, w/o Opal Jr. disks	1881	10.75	21.50
- software on Amiga disk	1841	11.00	22.00
Digital frequency readout for VHF/UHF receiver	926001-2	11.50	23.00
Inexpensive phase meter:			
- main board	930046	9.00	18.00
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- front panel foil	930046-F	17.25	34.50
X2404-to-8751 interfacing:			
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JULY/AUGUST 1993			
Active 3-way loudspeaker system	930016	21.50	43.00
Maxi micro clock			
- PCB	930020	15.50	31.00
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- cooking timer: ST62T10	7101	11.50	23.00
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Plant humidity monitor (supply)	934032	4.00	8.00
Four-fold DAC card for PCs:			
- GAL	6251	10.75	21.50
Multi-purpose display decoder:			
- EPROM 27128	6261	11.50	23.00
SEPTEMBER 1993			
Fuzzy logic multimeter -1	920049-2	20.00	40.00
Linear temperature gauge	*920150*	*7.05*	*14.10*
PC-aided transistor tester:			
- PCB	920144	9.75	19.50
- software on IBM PC disk	1781	7.50	15.00
Harmonic enhancer	930025	13.50	27.00
I^{2}C alphanumerical display:			
- PCB + disk (1851)	930044-C	14.25	28.50
- Software on IBM PC disk	1851	8.50	17.00
Mini micro clock			
- PCB	930055	7.50	15.00
- clock: ST62T15	7111	11.50	23.00
- darkroom timer: ST62T15	7121	11.50	23.00
- cooking timer: ST62T15	7131	11.50	23.00
950-1750 MHz converter	UPBS-1	1.95	3.90
OCTOBER 1993			
Stereo mixer	UPBS-1	1.95	3.90
MIDI channel monitor	930059	14.00	28.00
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Micr
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- board and ST62E15	920162-C	25.50	51.00
- ST62E15	7071	10.00	20.00
Fuzzy logic multimeter - 2:			
- PCB + Fuzzy Control One	920049-C	23.75	47.50
- Fuzzy Control One disk	1721	7.75	15.50
NOVEMBER 1993			
Precision clock for PCs:			
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- software on IBM Pc disk	1871	8.50	17.00
VHF/UHF TV tuner			
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- µC 87C51	7141	25.75	51.50
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- PCB + EPROM (6301)	930104-C	28.00	56.00
- EPROM 2764	6301	14.50	29.00
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DECEMBER 1993			
535 card with EPROM emulator:			
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SCART switching box	930122	14.25	28.50
1994			
JANUARY 1994			
SIM — an 8051 simulator:			
- software on IBM PC disk	1931	34.25	68.50
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RDS decoder:			
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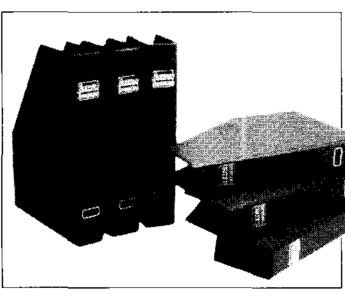

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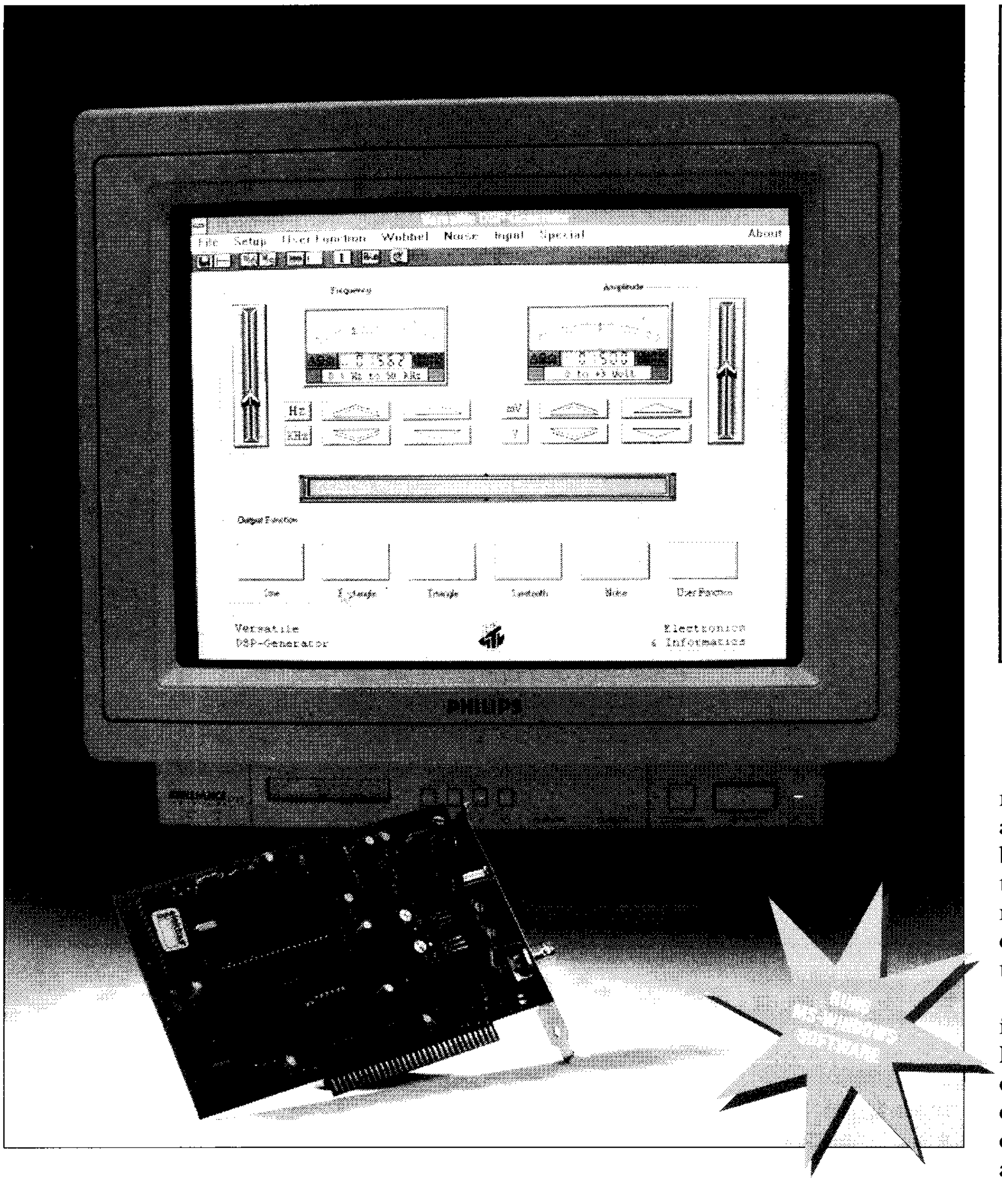
DSP FUNCTION GENERATOR



MAIN SPECIFICATIONS

Frequency range:	0.1 Hz to 20 KHz (sinewave, triangle and sawtooth).
Output voltage:	6 V_{pp} max.
Waveforms:	sinewave, triangle, rectangular, sawtooth, noise.
Resolution:	16 bits.
Software:	DOS or Windows.
PC bus:	8-bits XT slot.
DSP chip:	ADSP-2105.
Output socket:	BNC or 3.5mm stereo jack.
Output impedance:	47 Ω.

No electronics workshop or laboratory is complete without a function generator. The one described in this article is off the beaten track because it is not a stand-alone box with the usual set of controls on the front panel. Rather, it is an insertion card for PCs, and entirely controlled by software. The heart of the generator is a digital signal processor (DSP) chip from Analog Devices. The card is controlled by a 'plain DOS' or a Windows program supplied to you on disk. The Windows version even allows you to create your own waveshapes!

Hardware/software design by P. Hackl, M. Haidinger, R. Leeb and F. Reithuber

DIGITAL signal processors (DSPs) are typically found where digital and analogue electronics meet. A DSP is a special kind of microprocessor which, although a purely digital device, is capable of performing real-time operations on analogue signals 'in transit'. For example, a DSP uses microprocessor instructions to multiply, amplify, attenuate or filter analogue signals. Likewise, a DSP is capable of adding reverberation to a music signal by delaying the data flow of the digitized audio signal with the aid of a memory bank, and then adding it again to the main flow. Sure, that can be done with all-analogue electronics, too, for instance, with a bucket brigade memory, but then there is the inevitable noise, distortion, etc., to contend with and keep to a minimum.

The advantage of digital processing is that the quality of the digitized analogue signal is not affected during any operation. By contrast, in analogue circuits, the non-ideal characteristics of subcircuits give rise to distortion, and a decrease in the signal-to-noise ratio.

A DSP, of course, also has its limitations. The maximum frequency of the analogue signal, for instance, is limited by the processor's clock frequency. In practice, therefore, DSPs are best suited to processing low-frequency signals, leaving traditional, discrete, solutions firmly established for high-frequency techniques.

Circuit description

The complete circuit diagram of the digital function generator is shown in **Fig. 1**. The circuit is connected to the expansion bus of the PC. Consequently, all control is effected via software. An important link between the DSP system and the PC is the 82C55 PPI (programmable peripheral interface). Other key parts in the circuit diagram are the DSP proper (IC_1, an ADSP-2105), a D-A converter type AD1851 (IC_2) and a bootstrap EPROM type 27512 (IC_3). All other components

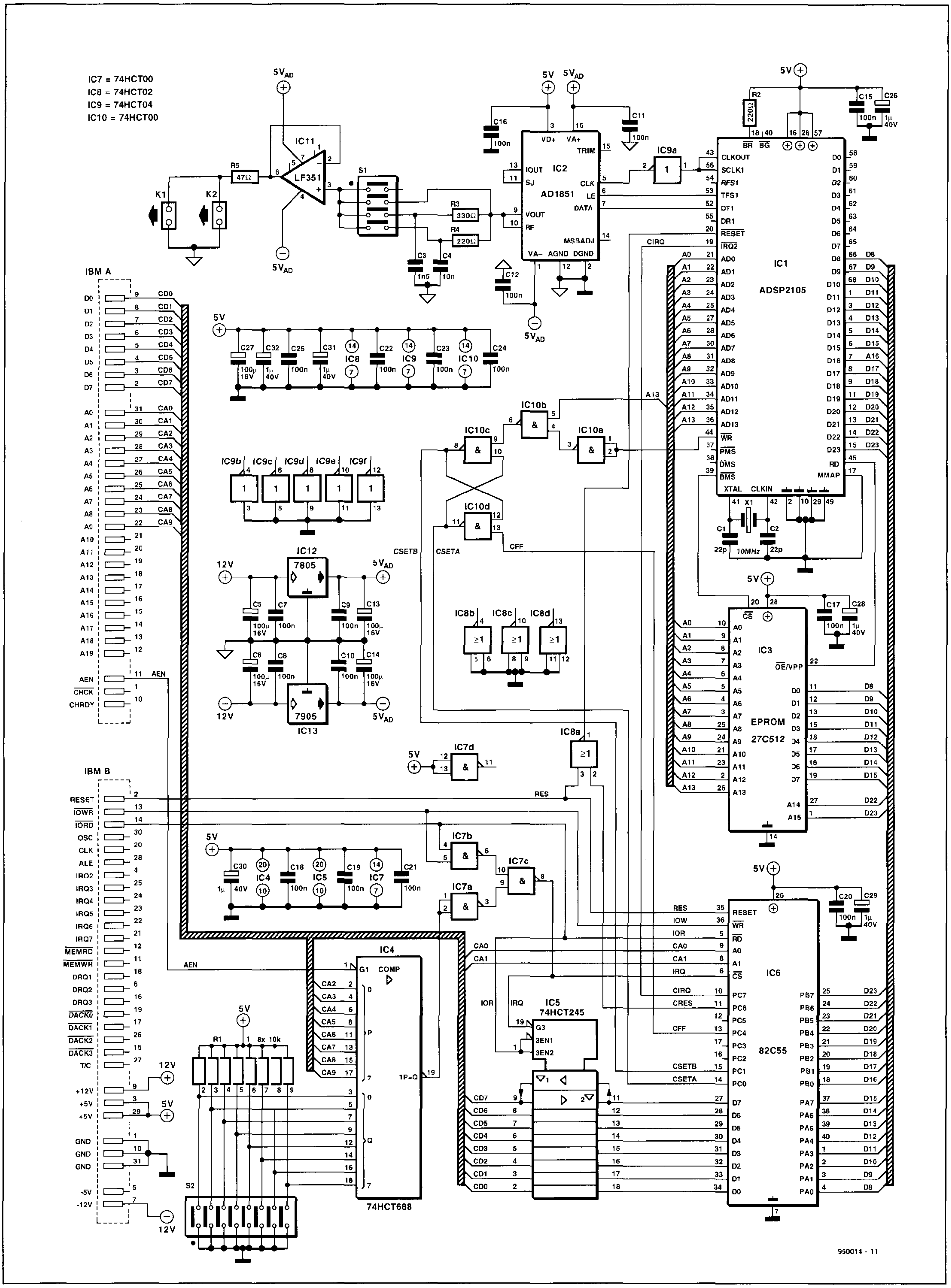


Fig. 1. Circuit diagram of the digital function generator. A digital signal processor (DSP) computes the waveform and sends it to a high-end PCM type D-A converter.

in the circuit are 'glue' between these key elements.

The EPROM, IC$_3$, is connected to the DSP only, and directly. The EPROM contains a set of codes which are loaded by the DSP to enable it to start ('boot') at power-on. The fact that the eight data outputs of the EPROM are connected to datalines D$_8$-D$_{15}$ of the DSP is not a mistake. The same goes for the circumstance that datalines D0-D7 of the DSP are not used. Inside the DSP, three 8-bit wide bytes are converted into a 24-bit word, which is subsequently stored in the program memory.

The block diagram in **Fig. 2** shows the structure of a circuit based on the ADSP-2105. The boot EPROM has a width of eight bits; the data memory and the I/O components have a width of 16 bits; and the program memory, a width of 24 bits. The external address bus of the ADSP is reserved for driving the EPROM. In addition, A13 and $\overline{WR}$ are used to generate an acknowledge signal via four NAND gates which mimic a bistable. The acknowledge signal is used by the processor to indicate that a command or instruction is understood. The computer can read back the acknowledge signal (CSTEA and CSTEB) via the 8255 PPI. It responds by returning a CFF signal which resets the acknowledge generator (i.e, the NAND-based bistable). Because the EPROM is only required to boot the DSP, there is no link between this memory and the PC's expansion bus. During the boot operation, the DSP fetches the code from the EPROM, and stores it its internal program memory.

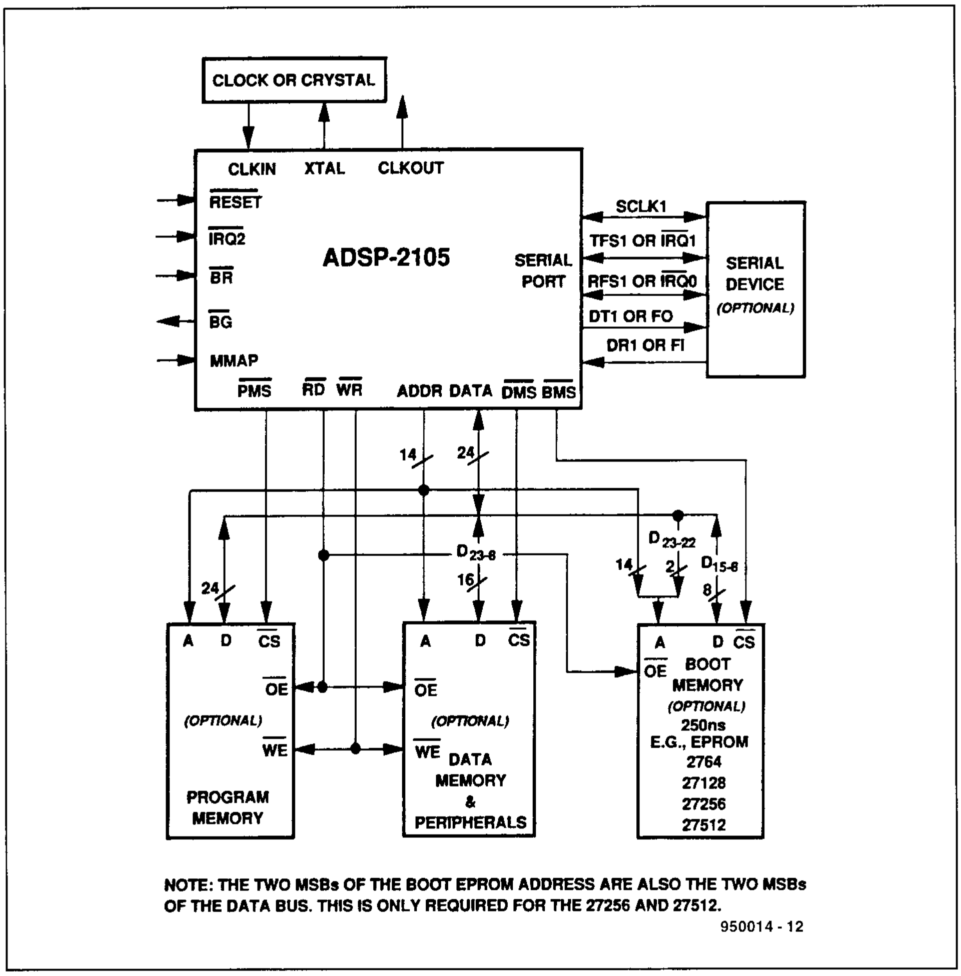


Fig. 2. The ADSP-2105 from Analog Devices uses three different bus widths, 8, 16 and 24-bit, for its memory functions.

The complete address bus, the chip select lines and the databus of the EPROM are connected to the DSP only. After the boot-up operation, the DSP no longer uses the code contained in the EPROM. It then waits until the system has to be started again.

The DSP supplies a serial data signal (DT1 on pin 52), a clock signal (CLKOUT on pin 43) and a flag signal (TFS1 on pin 53). The serial clock signal is applied to the digital-to-analogue converter (DAC), but it is also read back by the ADSP via the SCLK1 input, pin 56.

The DAC used is a type AD1851 PCM audio digitizer from Analog Devices. There is little to say about the DAC proper. The device has a resolution of 16 bits, and is suitable for triple oversampling (a feature which is not used in the present application). The signal to noise ratio is about 96 dB. The AD1851 is specially designed for use in high-end CD players, digital amplifiers, DAT recorders, synthesizers and keyboards. The maximum clock rate for the serial input data is 12.5 MHz. In the present circuit, a clock of 10 MHz is used.

The DAC output signal may reach buffer IC$_{11}$ via three different routes. DIP switch S$_1$ enables you to select a direct connection, without any kind of filtering, or the insertion of one of two passive low-pass filters. If the section consisting of R$_3$ and C$_3$ is selected, the roll-off frequency of the filter lies at about 320 kHz. If the other section, R$_4$-C$_4$, is selected, the roll-off frequency becomes 72 kHz. Switching off the filters is useful if noise or rectangular signals are required. The best waveforms are obtained when the 320-kHz roll-off is selected. Only the square waves are then 'rounded' a bit. The other roll-off, 72-kHz, is ideal for a perfect sinewave over the entire audio range. At higher frequencies, however, non-sinusoidal waveshapes are severely distorted by this setting, which is not suitable for generating white noise either.

After buffering by an LF351 opamp (IC$_{11}$), the signal is available on two outputs (K$_1$ and K$_2$) at an output impedance of 47 Ω.

The power supply is based on two integrated regulators, IC$_{12}$ for the +12 V line, and IC$_{13}$, for the –5 V line.

The last sections of the circuit to be discussed are the address decoder and the link between the 8255 and the PC. The address decoder compares the bit pattern set on switch block S$_2$ with that on address lines A2-A9. If the patterns match, and AEN is active, output $\overline{P=Q}$ drops low, and an enable signal is generated via IC$_7$. The enable signal is only passed, by the way, if IOR or IOW is active at the same time. When the selection signal is present, IC$_6$ is switched on, and its databus inputs receive the levels present on the PC's databus. Together with the low-order address lines A0 and A1, these drive signals RES (reset) IOW ($\overline{WR}$) and IOR ($\overline{RD}$), the selection signal enables the PC and the PPI to exchange data. Here, the 8255 takes four memory locations.

Construction

As already mentioned, the circuit is designed as an insertion card for PCs. The copper track layouts and the component mounting plan of the double-sided through-plated printed circuit board designed for the function generator are shown in **Fig. 3**. This board is available ready-made through the Readers Services, along with the control software on diskette, and the programmed EPROM.

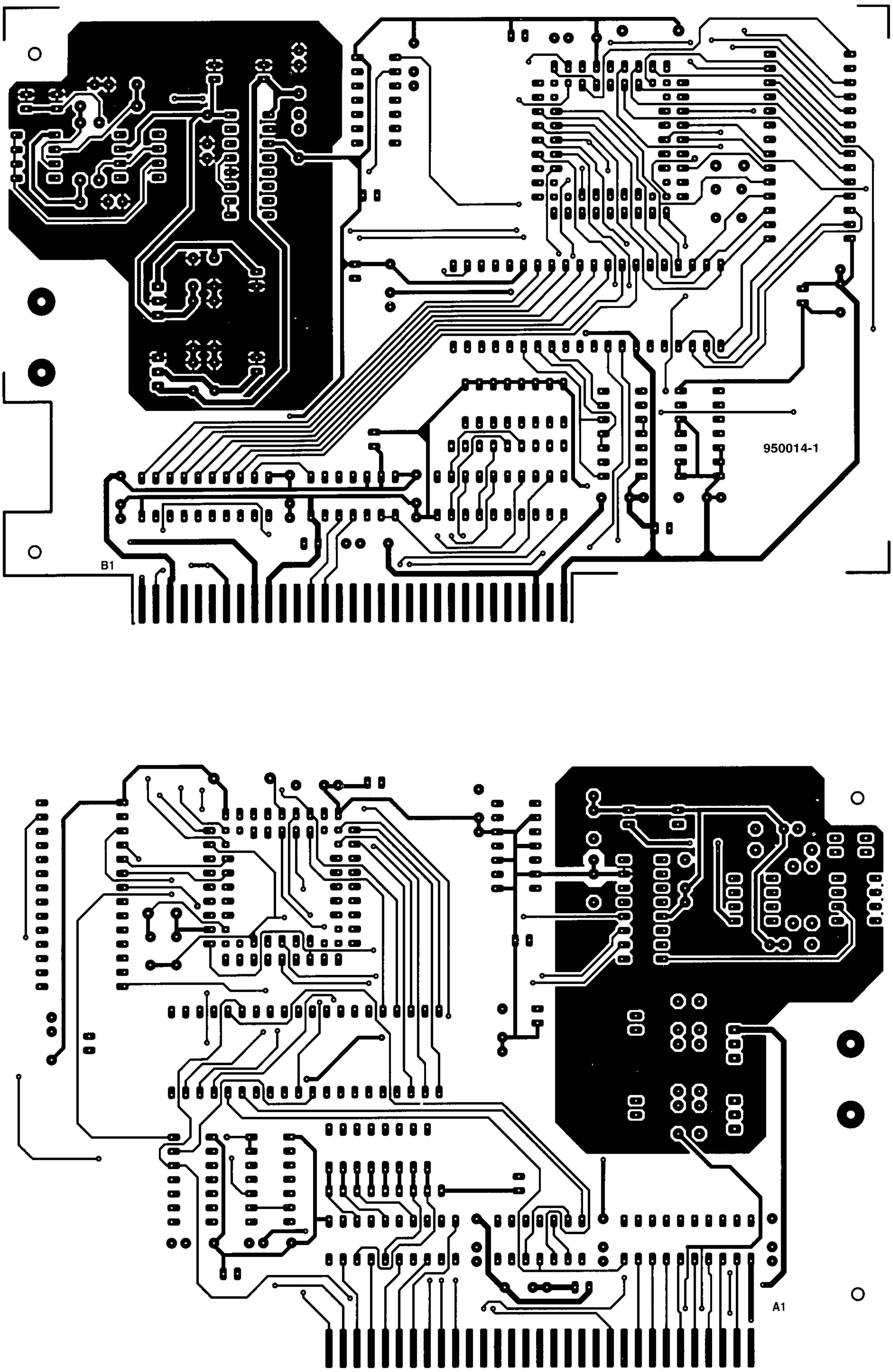


Fig. 3a. Copper track layouts (direct-reading) of the double-sided PCB designed for the function generator. Board available ready-made through the Readers Services (see page 78).

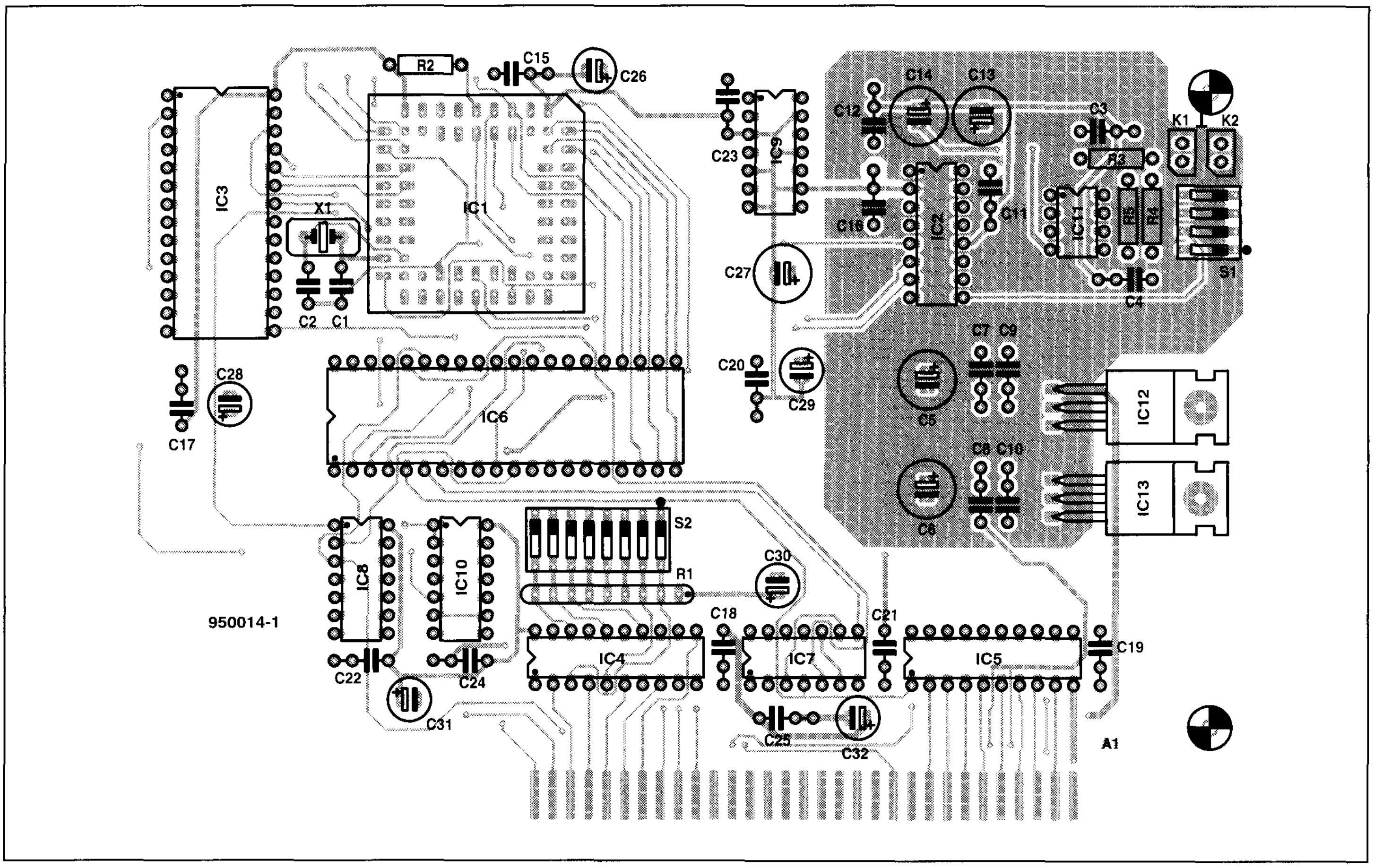


Fig. 3b. Component mounting plan.

Populating the PCB is mostly routine work, and is not expected to cause undue problems. It is recommenced to use good-quality sockets for all ICs, except, of course, the two voltage regulators. All electrolytic capacitors are radial types for upright mounting. Make sure of their orientation (polarity!) before soldering these devices in place. The same goes for the ICs, although these are fitted in sockets rather than soldered.

Connectors K_1 and K_2 are mounted on the PC insertion card fixing bracket before this is secured to the PCB. The BNC and 'jack' type sockets require holes to be drilled in the bracket. Some PCB material below the BNC socket has to be removed to leave room for the nut that holds the socket in place. The bracket should also have a rectangular hole through which the levers of DIP switch S_1 can be accessed.

Set the card address before inserting the card into a free expansion bus slot in the PC. The default address setting for this type of card is 300_H ('experimental' according to the IBM I/O standard), which is set with switches 3 through 8 to 'on', and switches 1 and 2 to 'off'. Initially, select no filtering by setting all switches in S_1 to 'off'.

Control software

Good as the hardware may be, it is

COMPONENTS LIST

Resistors:
R_1 = SIL array 8x10kΩ
R_2;R_4 = 220Ω
R_3 = 330Ω
R_5 = 47Ω

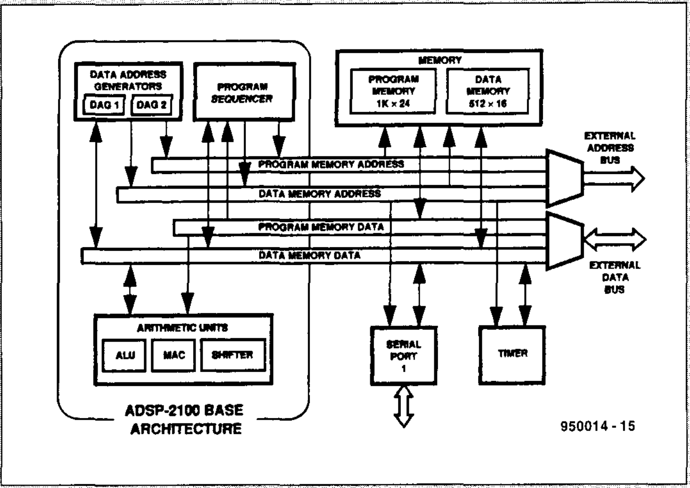
Capacitors:
C_1;C_2 = 22pF
C_3 = 1nF5
C_4 = 10nF
C_5;C_6;C_{13};C_{14};C_{27} = 100µF 16V radial
C_7-C_{12};C_{15}-C_{25} = 100nF
C_{26};C_{28}-C_{32} = 1µF 40V radial

Semiconductors:
IC_1 = ADSP2105 (Analog Devices)*
IC_2 = AD1851N (Analog Devices)*
IC_3 = 27C512 EPROM (order code 956501-1, see page 78)
IC_4 = 74HCT688
IC_5 = 74HCT245
IC_6 = 82C55
IC_7;IC_{10} = 74HCT00
IC_8 = 74HCT02
IC_9 = 74HCT04
IC_{11} = LF351
IC_{12} = 7805
IC_{13} = 7905

Miscellaneous:
K_1 = BNC socket.
K_2 = 3.5 mm dia. stereo headphones socket.
S_1 = 4-way DIP-switch.
S_2 = 8-way DIP-switch.
X_1 = quartz crystal 10 MHz.
Fixing bracket for PC insertion card, Vero type 427-59702K.
PCB, EPROM and disk: available as a set, order code: 950014-C (see page 70). Diskette also available separately: order code 956001-1.

* Analog Devices, Worldwide Headquarters, One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A. Tel. (+1) 617 329-4700, fax (+1) 617 326-8703.
UK distributors: Arrow Electronics Ltd. (01234) 270777; Jermyn Distribution (01732) 743743; Polar Electronics Ltd. (01525) 377093.
Kits for this project available from C-I Electronics, P.O. Box 22089, NL-6360-AB Nuth, The Netherlands. Fax (+31) 45 241877.

ADSP-2105 FROM ANALOG DEVICES



The ADSP-2105 is a single-chip microcomputer optimized for digital signal processing (DSP) and other high-speed numeric processing applications. Its instruction set is a fully compatible superset of the ADSP-2100 instruction set. It combines the complete ADSP-2100 architecture (three computational units, data/address generators and a program sequencer) with a serial port, a programmable timer, extensive interrupt capabilities and on-chip program and data memory RAM. The block diagram shows the structure of the processor, and the parts which belong to the basis architecture. The chip has 512 words of (16-bit) data memory RAM and 1 K words of (24-bit) program memory RAM on chip.

The ADSP-2105 is the industry's leading cost/performance DSP. It offers a direct upgrade path to more highly integrated and higher performance DSP processors such as the ADSP-2101 and ADSP-2111. Designers selecting the ADSP-2105 will be able to preserve their investment in ADSP21xx development tools requiring the added features found on the higher-grade DSPs in the 2100 family.

The ADSP-2105 is feature and instruction set compatible with the ADSP-2101. The only differences are the sizes of the on-chip memories (half the size of the ADSP-2101's), the number of serial ports (one instead of two) and the processor speed. The ADSP-2105 serial port (SPORT) is identical to SPORT1 of the ADSP-2101.

The ADSP-2105's flexible architecture and comprehensive instruction set support a high degree of operational parallelism. In one cycle the ADSP-2105 can:

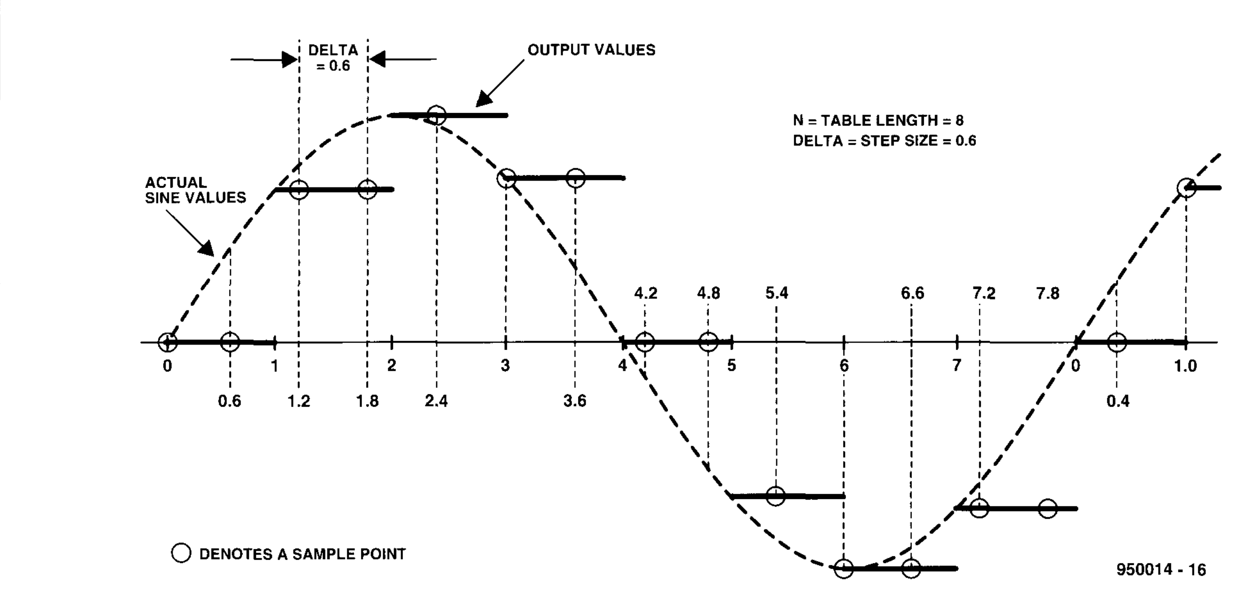
- generate the next program address
- fetch the next instruction
- perform one or two data moves
- update one or two data address pointers
- perform a computational operation
- receive or transmit data via the serial port

Fabricated in a high-speed double-layer metal CMOS process, the ADSP-2105 operates with a 100-ns instruction cycle time. Every instruction executes in one cycle. Fabrication in CMOS results in low dissipation. The ADSP-2105 dissipates less than 1 W under all conditions, and no more than 80 mW under standby conditions.

Digital signal generation

With periodic signals, samples of one period are stored in memory. Next, the successive values are sent one after one to the DSP's output. The frequency of the output signal may be changed by varying the step size at which data is fetched from a look-up table. The address generators contained in the ADSP-21xx processors allow this to be achieved in a simple way because the table start address, the step size and the table length can be programmed with the aid of individual registers. After fetching a table entry, the processor automatically increases the address by the desired step size. If the length of the table is exceeded, the pointer automatically wraps around to the start of the table. In this way, a cyclic buffer/table may be created, provided each waveform is described by a data from a separate table contained in the memory.

The serial datastream at the DSP's output is converted into an analogue signal by a DAC. The DAC is usually followed by a low-pass filter which removes the steps from the signal. The diagram below shows how a digital sinewave is created.



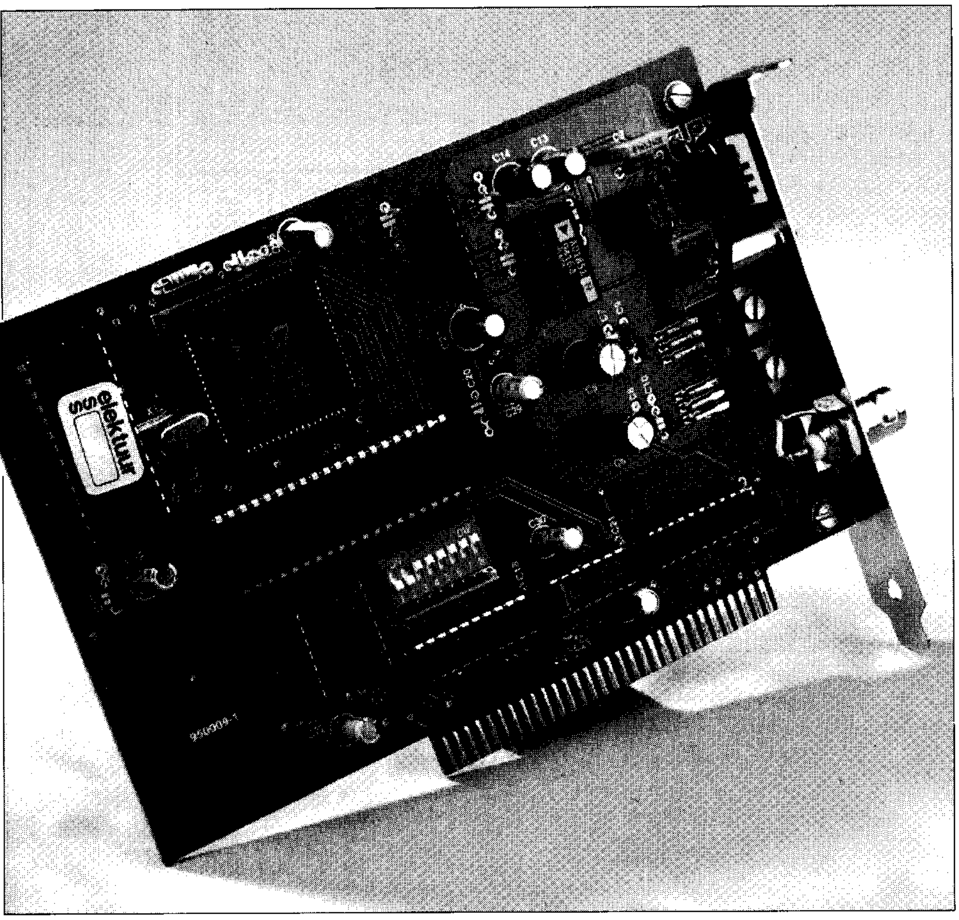
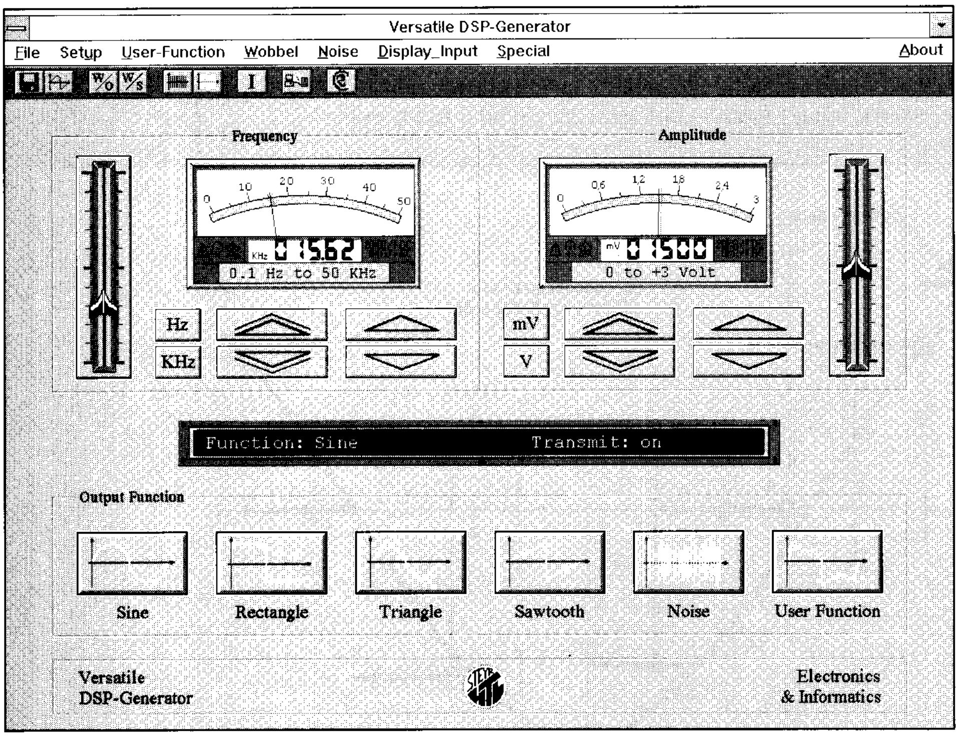


Fig. 4. Finished insertion card. The switches in block S_1 are accessible from the rear of the PC through a hole in the aluminium fixing bracket attached to the card.

useless without the appropriate software. The present project is supported by a couple of programs which allow the function generator to be controlled from DOS as well as from Windows. The Windows software is much more extensive than the DOS version, and offers extra features such as defining an arbitrary waveshape, a hearing test and a sweep (wobbulator) function.



Function: Sine Transmit: on

Fig. 5. Screendump of the Windows program. Note the two panel meters with combined analogue/digital readouts.

The DOS program, COMGEN, gives the DSP card the functionality of an ordinary, simple function generator for audio signals. It takes its commands and parameters from the DOS command line. Parameters are separated by a comma. When COMGEN is followed by a **?** or **Help**, all options are shown on the screen.

The DOS command format is

```
COMGEN P: A: F: type:
```

P:	sets the port address, for instance, 308. The desired address must be entered in hexadecimal after P:. The default address is 300.
A:	sets the output level (amplitude) in millivolts.
F:	sets the frequency in hertz.
type:	SIN for sine wave; REC for rectangular wave; TRI for triangular wave; SAW for sawtooth; WHI for white noise; PIN for pink noise.

The first time you use COMGEN after a system reset, it must be followed by a LOAD command. This resets the DSP card and starts the DSP program. For example:

```
COMGEN LOAD A:1000 WHI
```

causes the generator to supply white noise at an output level of 1 V. The card address is 300_H.

For Windows, too

Windows users are treated to the perfect looks of mouse-operated on-screen buttons and pull-down menus, in short, a graphics user interface. The Windows software is on the same diskette as the DOS program.

After installing the Windows version of the program, you are ready to operate the DSP card without bothering to consult the users' guide. The minimum requirements of the program are: Windows 3.1 or later, 2 MBytes free on the hard disk, and a VGA card.

After clicking away the title screen, the generator's control panel appears on the screen. The eye catchers are two large panel meters with combined analogue and digital read-outs. The left-hand meter indicates the set signal frequency, and the left-hand meter, the signal level. Six push-buttons and a slide potentiometer allow the frequency and the level of the generator output signal to be set as desired.

A menu bar at the top of the screen gives access to a number of specific functions including a swept-frequency generator (wobbulator), white or pink noise generator, and a hearing test. The menu bar also takes you into the advanced configuration options. A full-

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AD1851N	43.00
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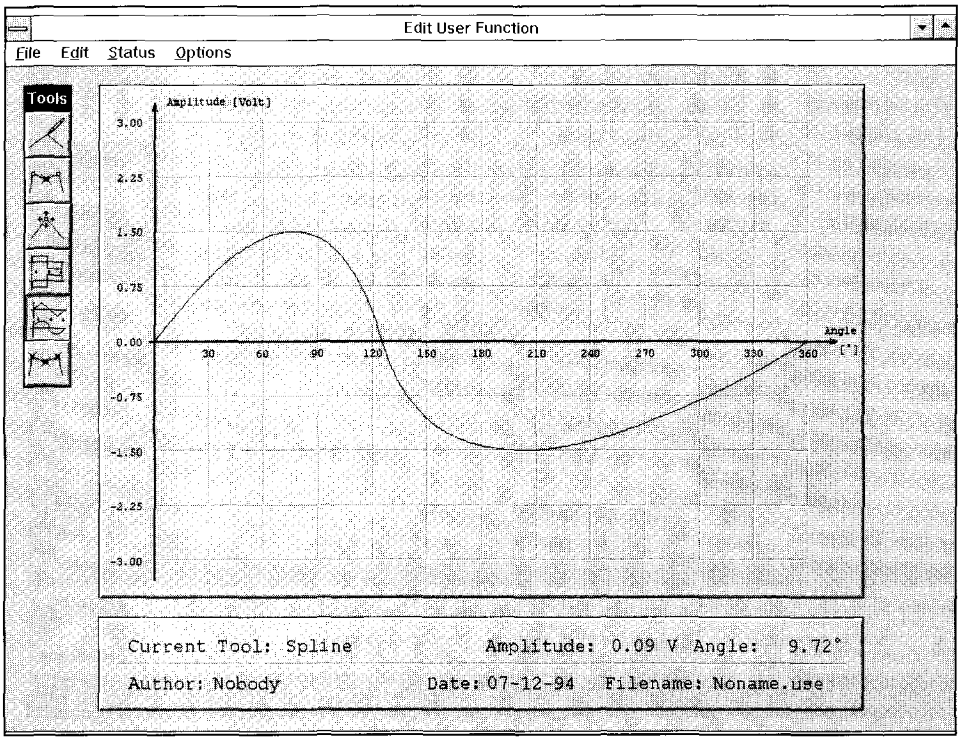

Current Tool: Spline Amplitude: 0.09 V Angle: 9.72°

Author: Nobody Date: 07-12-94 Filename: Noname.use

screen editor is available for the user to compose a waveform.

Six buttons at the bottom of the screen enable the desired waveform to be selected. If the 'user' function is selected, the edit screen for this function has to be opened via the menu bar. The tools which are then offered enable just about any waveform to be created — see **Fig. 6**.

Unfortunately, a full description of all features offered by the Windows software is beyond the scope of this article. However, the structure of the program is so clear that most questions can be answered simply by navigating through the different menus. Furthermore, a 17-page users' manual is available separately, which discusses the operation of the Windows software in great detail. The order code of this 'paperware' is **950014-P**.

(950014)

Fig. 6. The Wave Editor in action. Compose your own waveform by drawing it!

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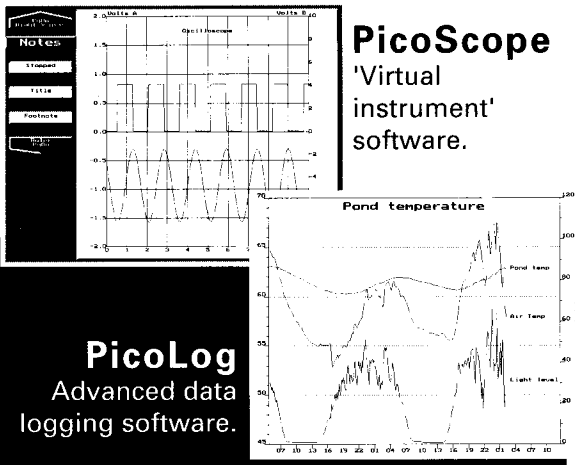

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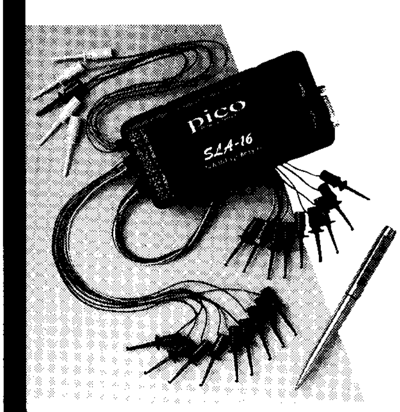

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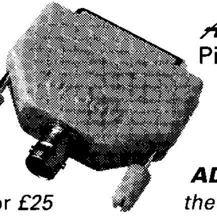

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THE DIGITAL SOLUTION

Part 4 – Analogue to digital

By Owen Bishop

In this series we look closely at digital electronics, what it is, what it does, how it works, and its promise for the future.

Last month we saw how binary information may be presented to a digital circuit. Binary information is essentially of the yes/no, true/false, off/on, high/low, variety. It has only two states or two levels. Much of the information we wish to process in a digital circuit is not like this. It is numerical information that can take any value within a given range. For example, we might wish to record digitally the temperature of a room, which may take *any* value within a range of, say, 5° to 35°. Or we may wish to process the rapid changes in air pressure that we call *sound*, or the brightness levels that go to make up a TV image.

The first stage in processing such quantities is to convert them into their electrical analogue values. Usually these values are expressed as voltages. These are not the same as those in a digital circuit, which can have only two values, low and high. Analogue voltages can take any value within a given range, and change smoothly from one value to another. The electrical analogue of a sound wave is a voltage whose changes are analogous to the changes in air pressure of the original sound. Before the analogue voltage can be processed in a digital circuit, we must convert it into its digital equivalent. For this, we use an *analogue-to-digital converter*, known briefly as an *ADC*.

Analogue quantities are represented in the digital circuit as numbers on the binary scale. The individual binary digits (or *bits*) have the value 0 or 1, and these values are represented by a low or high voltage. A binary number of several bits is represented by a number of registers set to 0 or 1, or by the low and high voltages on a set (or *bus*) of data lines. The more precisely we want to express the quantity, the more bits, register or data lines we use.

If we use eight bits, the range of possible values is from 00000000 to 11111111. This is from 0 to 255 in decimal, so there are 256 (=2^8) possible values. If the quantity is a voltage which may range from 0 V to 1 V, there are 256 steps in this range. One step (an increase of the binary value by 1) is equivalent to a value change of 1/256 = 0.0039 V. If we wish to express values more precisely than this, we must increase the number of bits. With 12 bits, the range is from 0 to 4095, with 4096 (= 2^{12}) possible values. The difference between adjacent values is reduced to 0.00024 V. In the circuit we describe below we assume that we are working with eight bits, but the operation of the circuit is the same, irrespective of the number of bits.

There are several distinct ways of converting values from analogue to digital form. We describe the most important techniques and outline their advantages and disadvantages. The circuit diagrams show the converters as a number of functional blocks. In most cases, it would be possible to assemble the converter from these units separately. But normally, the complete converter is available as an integrated circuit, needing perhaps only a few external capacitors and resistors.

Counter converter

The interesting point about the ADC in **Fig. 31** is that it is based on a DAC, a *digital-to-analogue* converter. The action of DACs will be described in a future instalment. For the present, we limit ourselves to saying that a DAC accepts a digital input and produces the equivalent analogue output within a range extending from 0 V up to a preset maximum. In the figure, the eight digital inputs, D_0 to D_7, of the DAC are fed from the outputs of an 8-bit counter. To start the conversion, the counter is reset so that all outputs are 0. Resetting and various other operations are performed by a simple control circuit consisting of a number of logic gates. The precise nature of the control circuit is not relevant to the description of the operation of the converter.

The all-zero input to the DAC results in it giving a 0 V output, and we assume that there is a positive voltage at the analogue input terminal. The + input of the comparator is therefore greater than the – input, so its output swings to logic high. A high input on one input of the AND gate caues its output to follow the level on the other input. Pulses from the clock pass through the AND gate and increase the counter. The increasing output from the counter passes to the DAC and its output rises. If this process is allowed to continue, the voltage from the DAC increases in 256 steps from 0 V up to the maximum. In a typical converter it is arranged that the voltage increases in steps of 0.01 V from 0 V to 2.55 V. For as long as the output from the DAC is less than the analogue input voltage, pulses continue to pass to the counter and the count increases. Eventually, provided the analogue voltage is not greater than 2.55 V, an incremental step takes the DAC output just above the analogue voltage. Instantly, the output of the comparator swings low and stays low. No more pulses pass to the counter, which remains registering the count it has reached.

A signal from the control circuit informs the next stage of the digital circuit that conversion is complete. The eight output lines indicate the binary value corresponding to the analogue voltage. In some converters, this value is held on a series of eight *registers* or *latches*, while the counter is reset and counting begins again to find the new value of the analogue input.

The counter converter is

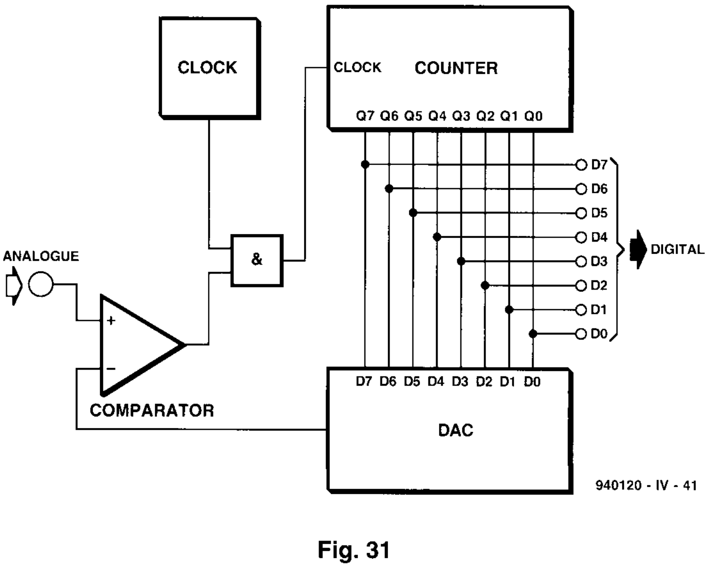

Fig. 31

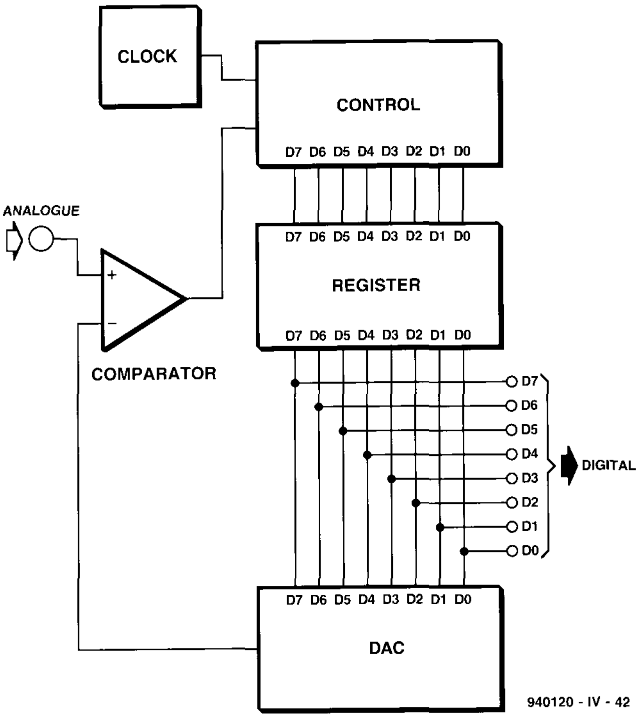

Fig. 32

Control output	DAC output (V)	Comparator output
00000000	0.00	high
10000000	1.28	low
01000000	0.64	high
01100000	0.96	high
01110000	1.12	low
01101000	1.04	high
01100100	1.00	low
01100110	1.02	correct; retain the present setting for that digit
01100111	1.03	high
01100110	1.02	correct; conversion complete

Table 1

available as an inexpensive IC, the ZN425E. It is easy to set up and use. One of its disadvantages is that it is slow. A more serious drawback is that the time taken for conversion depends on the analogue voltage. For example, with steps of 0.01 V, an analogue voltage of 0.05 V is matched after only five steps, but it takes 200 steps (40× as long) to match an input of 2 V. This means that a relatively high input voltage is sampled less often than a low input, so rapid changes in the voltages are followed less accurately. Another point is that the input is allowed to change while counting proceeds. Sometimes, the input may be increasing slightly ahead of the count, whereas at other times it may fall to meet the count. As a result of this, the input is converted at irregular intervals.

A variation on the counter type of ADC has the clock pulses going directly to the counter, and there is no AND gate. The counter is an up/down type, with an 'up' input and a 'down' input. The counter is increased on each clock pulse when the 'up' input is high, but decreased when the 'down' input is high. Both inputs are fed from the comparator and there are two situations:

1. analogue input higher than DAC output → comparator output high → counter increased.
2. Analogue input lower than DAC output → comparator input low → counter decreased.

This makes the counter follow the changes in analogue input instead of being reset and having to count up for every conversion. If the analogue input is varying by fairly small amounts between consecutive conversions, the counter never has far to count to match the DAC output to the analogue input. It may take only a few steps for each conversion, which makes conversion much quicker and more accurate. Also, conversions are completed at more regular intervals.

The main disadvantage of the tracking counter ADC is that, if the input voltage is constant, the counter is made to count up and down alternately at each conversion, which causes its output to oscillate.

Successive approximation

An ADC using *successive approximation* is shown in **Fig. 32**. It has some features in common with the counter type: it has a DAC, clock, and comparator, but no counter. Instead of the counter, it has a control circuit which feeds its output to an 8-bit register. The register holds the values it receives from the control, and passes them to the DAC. The clock causes the control to step through its program.

At the beginning of a conversion, the register is set to 00000000 by the control and the output of the DAC is 0 V. The analogue input is greater than this, so the comparator output swings high. This level causes digit D_7 of the control to go high, so that its output is 10000000. This is held in the register and fed to the DAC. The effect of this is to cause the output of the DAC to rise to its half-way value. For example, if the maximum value is 2.55 V (equivalent to 256 steps, or a count of 11111111), the output is 1.28 V. If the analogue input is *greater* than this, the comparator output remains high and the next digit, D_6, is made high. The value 11000000 produces a DAC output of 1.92 V. However, if the analogue input is *smaller* than 1.28 V, D_7 is made 0 and D_6 is made 1. The value 01000000 makes the DAC output change to 0.64 V. Suppose that the analogue input is smaller than 1.28 V, but greater than 0.64 V. The range of possible voltages has been narrowed down. At the next clock pulse, the control output is changed to 01100000 (0.96 V) and, assuming this turns out to be too high, to 01010000 (0.80 V). The range has been narrowed to 0.64–0.80 V.

Working along the row of digits, the control circuit cuts the remaining range into two halves at each stage and decides whether the analogue input is in the upper half or lower half of the range. This is the technique of successive approximation. It homes on the correct analogue value in nine clock pulses.

To make the routine clear, follow the sequence as it homes on an analogue input of 1.02 V (see **Table 1**, in which the newly changed digit is underlined).

The binary search for the correct value, continually halving the range and selecting the appropriate half, is fast. It makes this type of ADC one of the fastest of those described here. There is one slight complication: if the analogue voltage is changing rapidly, the circuit might not home on it

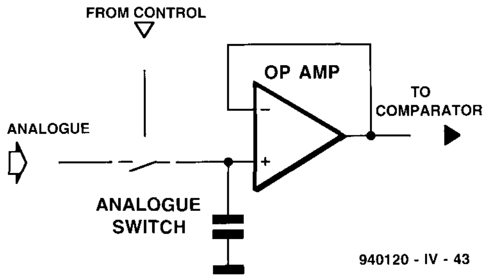

Fig. 33

sufficiently quickly. The input might 'slip through the net' and not be found. To guard against this, it is necessary in some high-speed applications to hold the analogue input constant while it is being converted. This is done by the use of a *sample-and-hold* circuit.

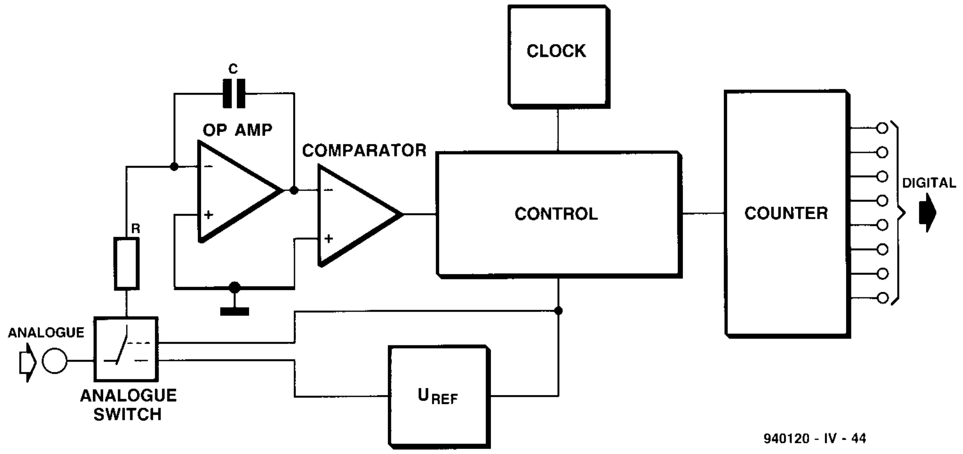

Fig. 34

A typical sample-and-hold circuit is shown in **Fig. 33**. The analogue switch is a digitally controlled (or electronic) type. Unusually for a digital circuit, its input can take any value between 0 V and the +ve supply voltage, and its output takes the same value as its input. When the control input is low, the input and output are isolated from each other, with a typical leakage current of 1.5 nA. When the control is high, the switch is turned on and has an input-to-output resistance of about 250 Ω. To sample the analogue voltage, the switch is turned on by a high pulse from the control circuit. During this pulse, the capacitor is charged to the input voltage. When the pulse ends, the switch is turned off and the capacitor holds its charge; it can not leak away through the switch. The operational amplifier has a very high input impedance, so the charge can not leak away in that direction, either. The op amp is wired as a voltage follower, so its output equals the sampled voltage and is converted to digital form by the ADC. The switch is then opened to allow the capacitor to be recharged to the most recent analogue level, ready for the next sampling.

Dual slope integration

The dual slope integration type of ADC relies on an entirely different principle. It is based on an op amp wired as an integrator as shown in **Fig. 34**. At the beginning of a conversion cycle, the capacitor is discharged, and the counter is reset to zero. The double-throw analogue switch is set to connect the op amp to the incoming analogue voltage. The output of an integrator is a ramp and, assuming the capacitor is discharged to begin with:

$$U_{\text{out}} = (-1/RC)\int_0^{t_c} U_{\text{in}}\,\mathrm{d}t$$

The control lets the output ramp down (or up, if the analogue voltage is negative) for a fixed number of clock pulses. We will assume that the input is negative and that the output voltage ramps up to $+U_t$. Then, the analogue switch is changed to connect the op amp to a reference voltage. The reference voltage has the opposite polarity to the analogue input. This is easily arranged, because the comparator will already have informed control of the polarity of the charge during the charging phase.

The discharge phase lasts for as long as it takes the capacitor to become discharged to bring the op amp output back to zero. The length of this phase, t_d, is measured by counting clock pulses. During the charging phase, the slope of the ramp at any instant depends on the magnitude of the analogue voltage, but the time of charging is fixed. The output voltage reached by the op amp depends on the average analogue input and on *R* and *C* (see **Fig. 35**). During the discharge phase, the slope of the ramp is fixed. The time taken to reach zero depends on the slope and the output voltage reached at the end of the charging period. Since U_t is proportional to U_{in} and t_d is proportional to U_t, t_d is proportional to U_{in}. *R* and *C* merely act as scale factors and apply to *both* periods, so their

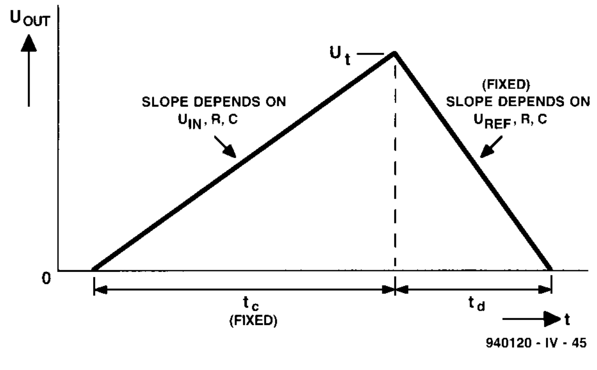

Fig. 35

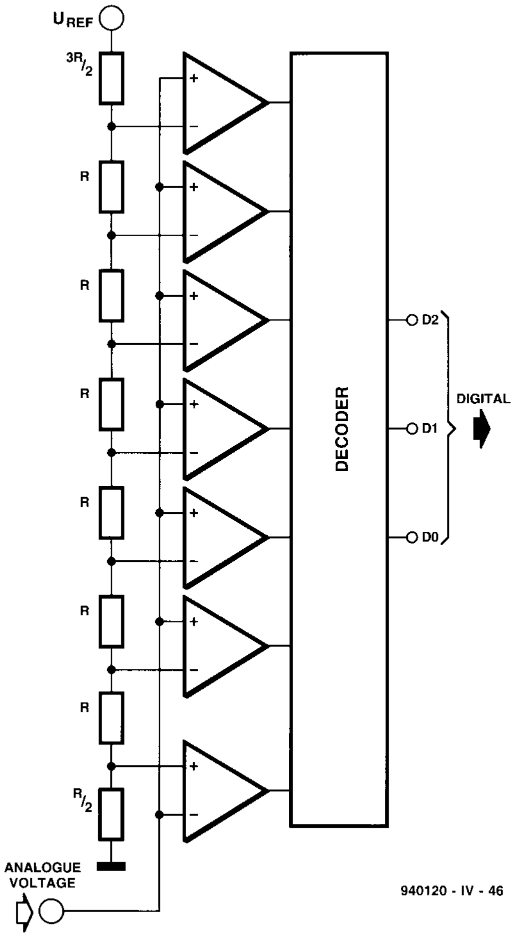

Fig. 36

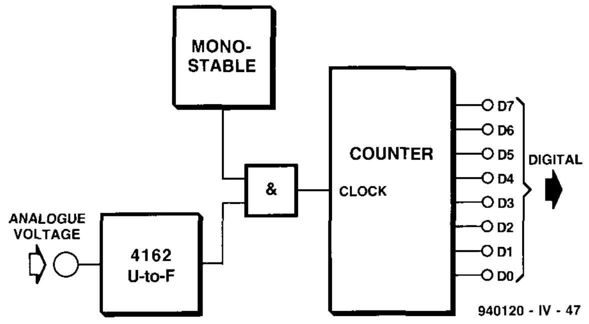

Fig. 37

values cancel out of the calculation. We are left with:

$U_{in} = -U_{ref} \times t_d/t_c.$

We have already noted that the values of R and C do not affect the calculation of U_{in}. This means that the precision of the conversion does not rely on the use of a high-precision resistor and capacitor. The result is unaffected even if the resistor and capacitor values change over a period of time owing to ageing. In addition, the charging and discharge times appear in the equation as a *ratio*. We need to count only the *numbers* of clock pulses (easy to do digitally), but the precise length of the pulses is unimportant. Finally, the integrating action of the op amp means that it is the average value of U_{in} that is being measured. Noise on the input is largely ignored. The only critical value in the equation is that of the voltage reference; a high precision reference is essential and is easily provided.

As a result of the factors listed above, the dual slope ADC has high precision and stability. For this reason, it is often used in instrumentation applications, such as digital voltmeters.

Flash converter

The converters described so far all rely on counting circuits and an appreciable time is required, therefore, for each conversion. An 8-bit successive approximation converter, for instance, with a typical clock rate of 900 kHz, requires nine clock periods, that is, 10 µs. One hundred thousand conversions per second is, however, more than the other types can achieve. Although such a high conversion rate is adequate for most purposes, there are applications where higher rates are essential. For example, conversion of analogue video signals in real time requires several million samples per second, often to at least 12-bit accuracy. For purposes such as this, we use flash conversion which, as its name implies, is very fast. The principle is illustrated in **Fig. 36**, which shows a 3-bit converter.

For a resolution of n bits, we have a chain of 2^n resistors, fabricated on a silicon chip, connected between a reference voltage and ground. The result is a series of tapping points at precisely known and equally spaced voltages. If the resistor value is R, with the top resistor $3R/2$ and the bottom resistor $R/2$, the voltage across each resistor is $U_{ref}/2^n$. The voltage at each tapping point is compared with the input analogue voltage by a series of comparators. We need (2^n-1) comparators. For a given input voltage, there will be a number of comparators at the lower end of the chain which have a logic high output because the analogue input voltage is greater than their reference voltage. The remaining comparators will have a logic low output. The outputs of the comparators are decoded by a logic circuit which produces a digital output representing the input voltage. The time taken for conversion is simply that required for a comparator to settle to a stable output level, making it possible to perform ten million or more conversions per second.

The main disadvantage of this type of converter is the large number of comparators required. An 8-bit converter needs 255 comparators. This order of accuracy is not always required in video circuits, so 6-bit converters are made that need only 63 comparators.

Voltage to frequency

As mentioned earlier, there is a tendency in digital circuitry, especially with the falling cost of microprocessors and microcontrollers, to replace hardware solutions by software solutions. The converters described so far in this article are essentially hardware. Their output is a binary number which can be used directly by subsequent digital circuits. A *voltage-to-frequency* (*U*-to-*f*) converter performs only part of the analogue-to-digital process, leaving the final stages to be performed by software.

A *U*-to-*f* converter is a voltage-controlled oscillator with a square-wave output. The VCO found in the 4046 phase-locked loop IC described in an earlier instalment can be used as a simple converter. The difficulty is that its response is not perfectly linear, so it is unsuitable for use in several applications. The 4152 is a VCO with 1% linearity. It generates a square-wave output in which the pulses are of equal length and their frequency is proportional to the input analogue voltage. The output from the IC can be fed to a counter IC as in **Fig. 37**. All that is needed to complete the circuit is a monostable to feed pulses from the IC to the counter for a fixed length of time. The count is proportional to the analogue voltage.

An alternative technique is to feed the output from the converter directly to an input port of a microcontroller system or microcomputer. Software monitors the input and counts the number of pulses received during a given period of time. Note that it is possible to have a long lead joining the converter to the computer, making this type of converter suitable for remote measurements.

Voltage to time

Voltage-to-time conversion is another technique that lends itself to software processing. The 507C is a low-cost IC that is able to perform a 7-bit conversion, typically in 1 ms. It is a *single-slope* converter that consists of a counter driven by an external clock and a DAC which produces a descending ramp voltage—see **Fig. 38**. The ramp voltage is continuously compared with the input analogue voltage. Provided that the input voltage is greater than 200 mV, the output of the IC goes high whenever the ramp voltage exceeds the analogue voltage. Thus, we obtain a series of pulses at a fixed frequency ($^1/_{64}$× the clock frequency) but with a *pulse width* proportional to the input

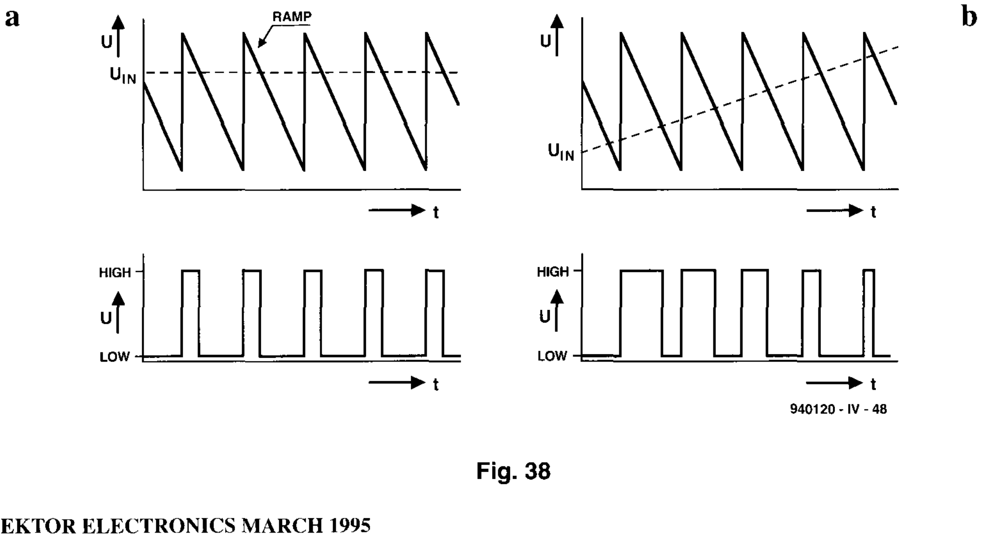

Fig. 38

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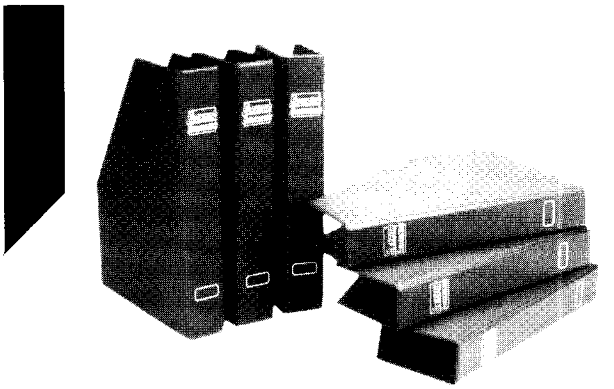

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voltage. Figure 38b shows the pulse width gradually decreasing as the input voltage increases.

In a digital application, the output of this converter is fed to the input of a digital timing circuit or to a microcontroller system. The length of the high pulses is measured and, from this information, the value of the input analogue voltage is calculated. As in the previous example, the output is suitable for transmission along a wire and may be used, therefore, for remote sensing. One point to notice is that this is not an analogue-to-digital converter: it converts one analogue quantity, voltage, into another analogue quantity, time. But time is an analogue quantity that is more easily measured by software.

[940120-IV]

Test yourself 4

1. Make a table of the successive approximation in an 8-bit ADC (Fig. 32) if the maximum analogue input is 2.55 V and actual input is 0.45 V.
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3. A flash converter has a 4-bit output. How many comparators does it need? If the reference voltage is 5 V, what is the voltage across each of the resistors in the chain?

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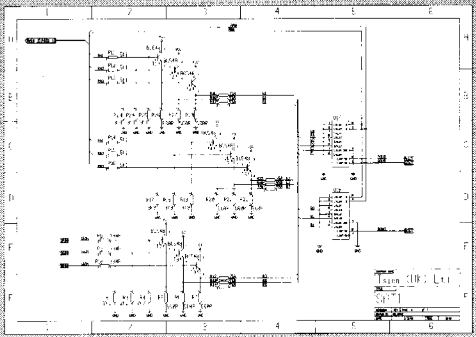

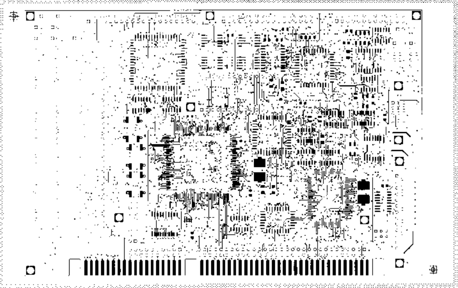

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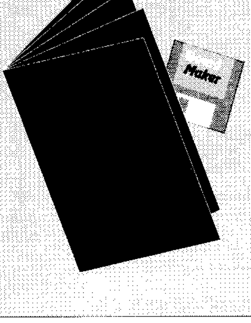

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TELEPHONE-CONTROLLED SWITCH

Design by H. Kiprowski

A switch, based on a PIC[1] RISC[2] processor, is described that enables mains-operated equipment, such as a computer, a coffee maker, or the central heating to be switched on and off via a telephone line.

The 'teleswitch' is operated via a telephone line and can switch the mains on and off as often as required. It is well-protected against unauthorized use and can be switched to manual operation so that it need not be unplugged when the user is at home. Moreover, it does not increase the telephone bill since it reacts to the bell signal: communication need not be established.

The switch is based on a CMOS RISC processor Type PIC16C54LPOTP from Microchip. This processor contains 12 I/O lines that can be programmed individually, its own clock oscillator, programmable internal registers that can serve as RAM, and 512 bytes of ROM.

The letters LP stand for Low Power, indicating that the processor draws a minute current only.

The last three letters in the type coding indicate One Time Programmable. This means that the PIC can be programmed only once: it can not be erased. This type of PIC is significantly less expensive than the types with a window and EPROM that can be programmed and erased many times.

The clock signal may lie between d.c. and 400 kHz. Since in the present application the low-frequency telephone signal is used, an inexpensive 32.768 kHz crystal can be used.

Circuit description

The circuit—see **Fig. 1**—consists of four distinct sections: power supply, telephone interface, PIC and a relay-operated switch.

The telephone interface is connected to the telephone line via terminals **a** and **b**. Capacitors C_7 and C_8 prevent the direct voltage on the telephone line entering the switch: only the 48 V bell signal is passed by them. This alternating voltage is half-wave rectified by D_2 and limited to a level of –0.7 V to +4.7 V. This voltage is applied to the LED in optoisolator IC_3, which then lights. Resistor R_5 keeps the current within safe values. When the telephone bell rings, a rectangular voltage of about 5 V appears on the collector of the optotransistor and thus at input RB_3 of IC_1.

When the PIC is actuated by a bell signal or manually by S_1 being pressed, its output RB_0 becomes high. This switches on T_1, which in its turn energizes the relay. Socket K_2 is then connected to the mains via plug K_1.

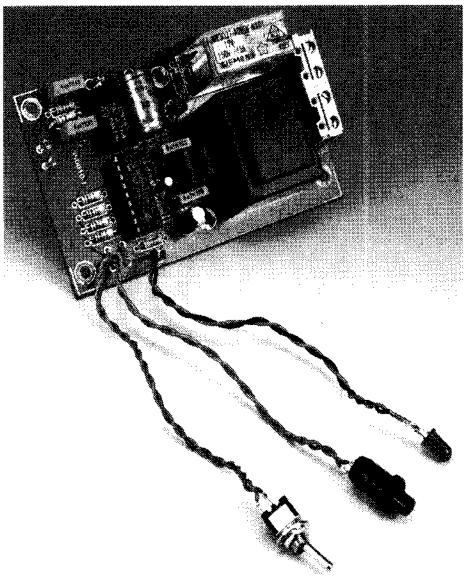
Inputs RB_1 and RB_2 of IC_1 are held high via pull-up resistors R_1 and R_2 when both S_1 and S_2 are open.

The internal clock oscillator is controlled by crystal X_1.

Diode D_3 is a function indicator.

Both IC_1 and IC_3 are powered by a simple, regulated 5 V supply provided by B_1, IC_2, and capacitors C_1–C_4.

The relay is energized by the unregulated 14 V at the +ve terminal of the bridge rectifier. The relay contacts are rated at 5 A. The constant-power rating of the relay is 1200 VA.



Program

The program stored in the PIC ensures simple control of the switch. It starts automatically when the switch is connected to the mains and immediately checks whether S_2 is open or closed. If this switch is open, RB_1 is high: the processor is then in manual control mode. In this mode, the switch is operated by pressing S_1.

The 'teleswitch' acts as a remote

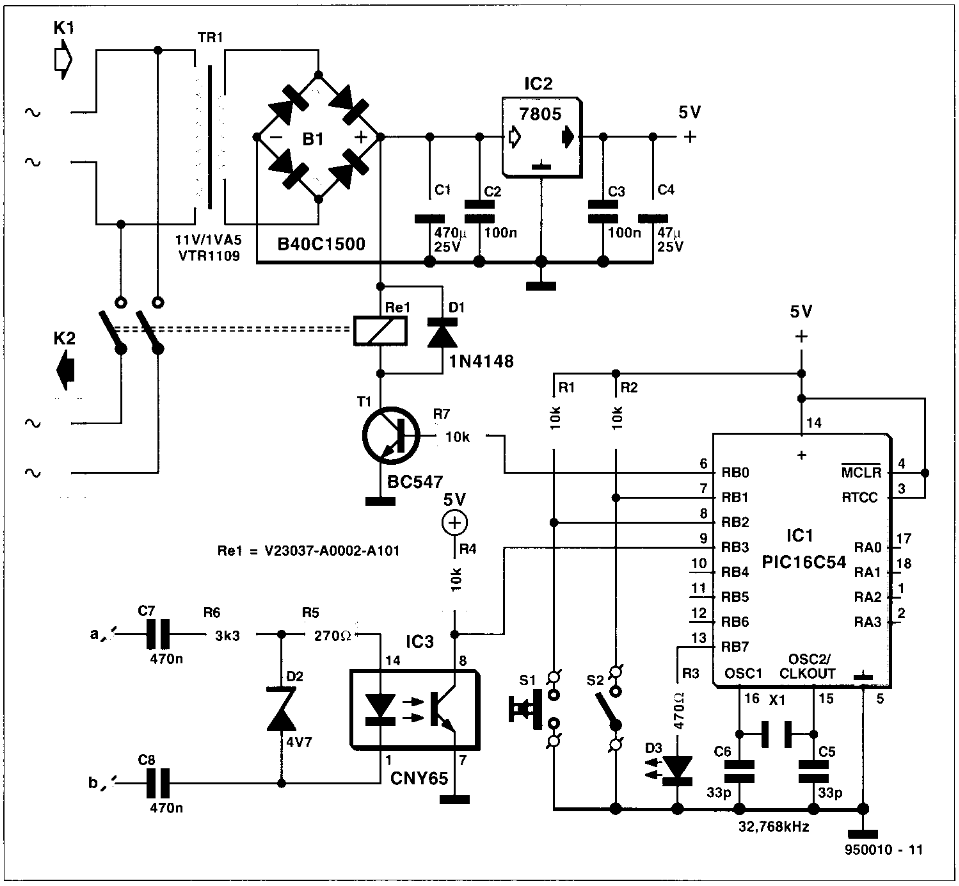


Fig. 1. Circuit diagram of the telephone-controlled switch.

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[1] = Peripheral Interface Controller

[2] = Reduced Instruction Set Coding

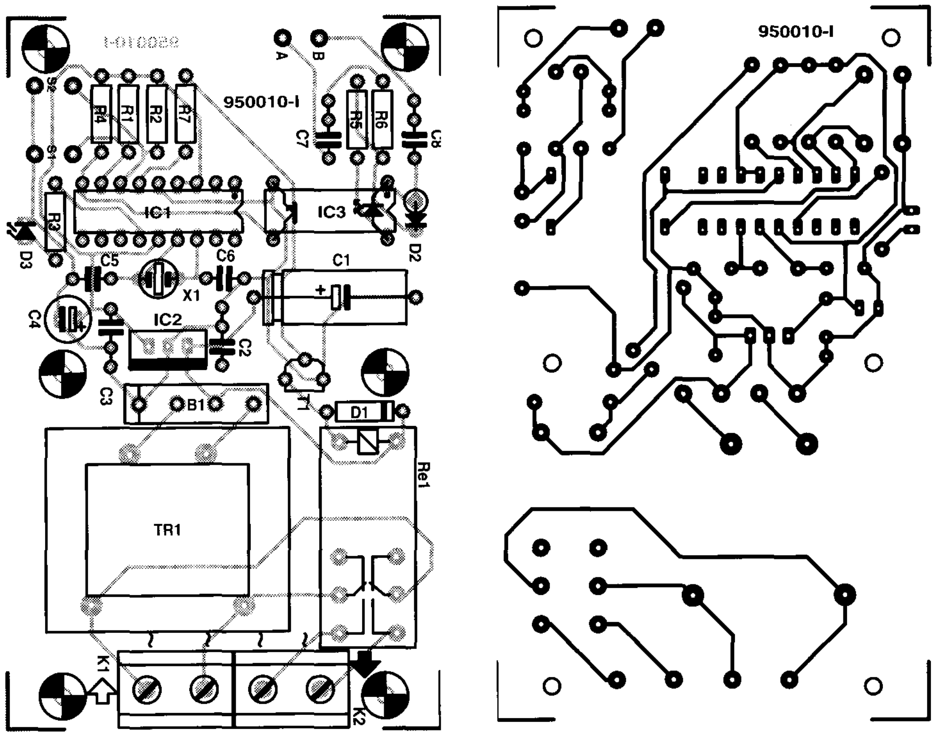

Fig. 2. Printed-circuit board for the telephone-controlled switch.

controlled unit when S_2 is closed; the state of S_1 is then immaterial.

When S_2 is closed, input RB_3 is monitored to ascertain whether a valid bell signal is received. A bell signal is valid only if it consists of one call tone only. Thus, the remote operator dials the number of the telephone, lets it ring once only and then returns the handset to the cradle.

The program waits for seven seconds after the call has been received. If during that time no further bell signal is detected, output RB_7 is actuated, whereupon D_3 lights to indicate that the first part of the input code has been accepted. A second internal counter then enables the caller to repeat the call within 50 seconds.

Fig. 3. Completed switch.

Only if within this period the bell rings once and not again within seven seconds, the total code is accepted as valid. Output RB_0 then changes state, whereupon D_3 goes out to indicate that the switch is in the standby mode.

Since many electronic telephone exchanges generate a short initial call tone, the program is arranged to ignore this first ring if the second follows within two second. This means that a bell signal is not valid when the interval between two rings is longer than two and shorter than seven seconds. The program is also interrupted when the interval between two rings is longer than 50 seconds.

When a bell signal has been judged invalid, the switch immediately reverts to its standby mode.

Note that manual operation can be selected with S_2 in either operating mode.

If the switch is used to switch a computer on, an acknowledgment from the computer may be arranged via its modem.

Without PC and modem, a control acknowledgment may be arranged via a (existing) telephone answering machine, which must be connected in parallel with the equipment or device to be switched. In that case, if, on a second call, the answering machine comes on line, it is certain that the equipment or device has been switched on.

Construction and installation

The 'teleswitch' should be built on the printed-circuit board shown in **Fig. 2**. The PIC and optoisolator are best fitted in appropriate sockets to enable them to be changed easily. It is advisable to cut any terminals protruding from the track side of the board as short as possible to prevent them piercing the insulation of the connecting wires running beneath the board. It is, actually, advisable to separate the board from these wires by a thin sheet of perspex or other insulating material.

If possible, fit the board in an enclosure already fitted with a mains plug and socket. Connec K_1 to the plug and K_2 to the socket.

Terminals **a** and **b** of the switch are connected via a length of (two-wire) telephone cable to the relevant pins of an appropriate plug that fits in the telephone socket. Since these sockets vary from country to country, no further information on them can be given. Note by the way that in certain countries it may not be allowed to connect the 'teleswitch' to the public telephone network: seek advice from your local telephone authority. There is, of course, no objection to using it with a private telephone system.

Parts list

Resistors:
R_1, R_2, R_4, R_7 = 10 kΩ
R_3 = 470 Ω
R_5 = 270 Ω
R_6 = 3.3 kΩ

Capacitors:
C_1 = 470 μF, 25 V
C_2, C_3 = 100 nF
C_4 = 47 μF, 25 V (upright)
C_5, C_6 = 33 pF
C_7, C_8 = 470 nF

Semiconductors:
D_1 = 1N4148
D_2 = zener, 4.7 V, 500 mW
D_3 = LED
T_1 = BC547

Integrated circuits:
IC_1 = see miscellaneous
IC_2 = 7805
IC_3 = CNY65

Miscellaneous:
K_1, K_2 = two-terminal strip, pitch 7.5 mm
S_1 = press-to-make switch
S_2 = single-pole on/off switch
B_1 = B80C1500 rectifier
X_1 = crystal, 32.768 kHz
Re_1 = 12 V, 1200 VA, 2-contact relay
Tr_1 = Mains transformer, 9 V, 1.5 VA secondary, e.g. Velleman 1090018 (Maplin)
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[950010]

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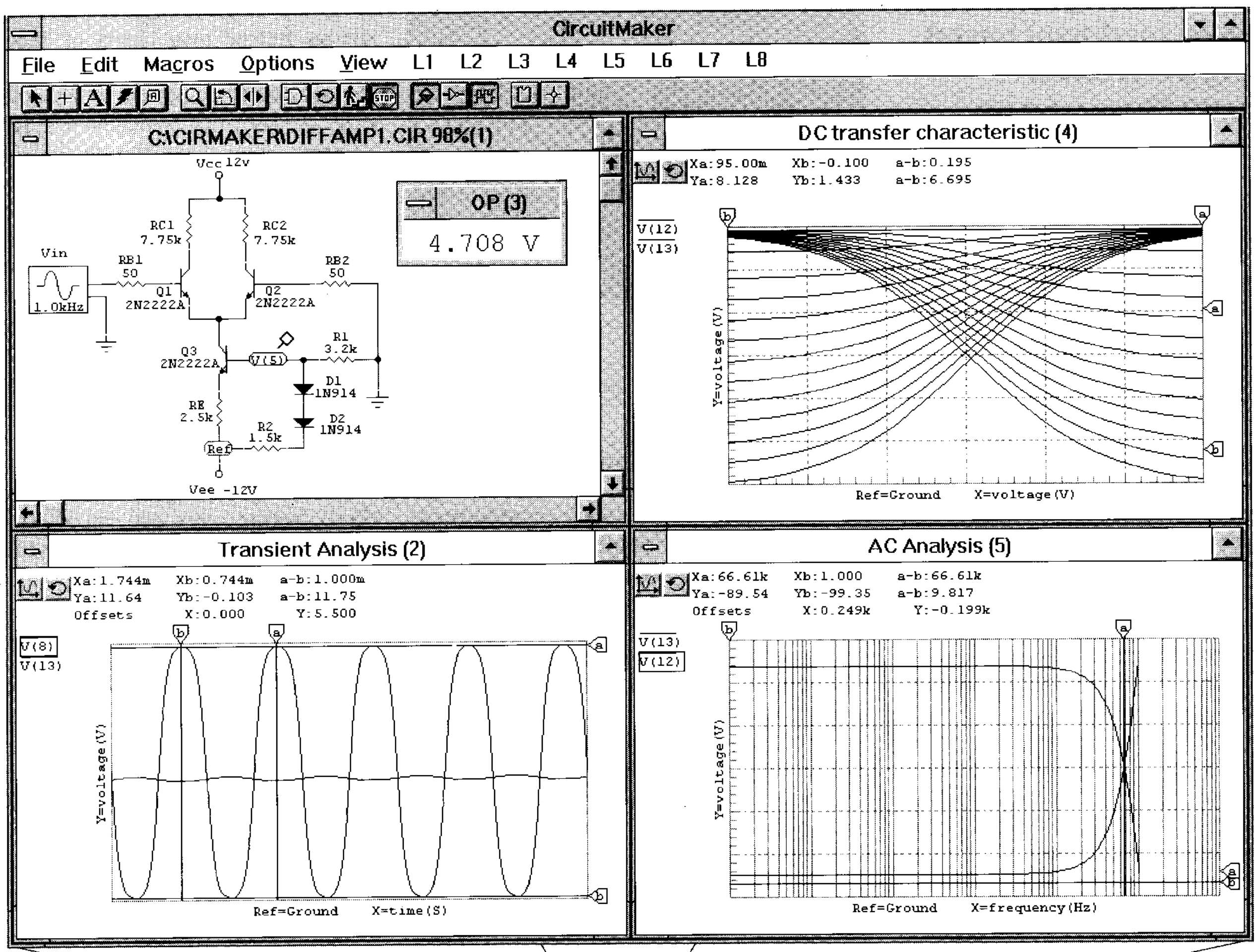
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RC1 7.75k
RC2 7.75k
Vin
RB1 50
RB2 50
1.0kHz
Q1 2N2222A
Q2 2N2222A
Q3 2N2222A
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R1 3.2k
D1 1N914
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Ya:8.128 Yb:1.433 a-b:6.695
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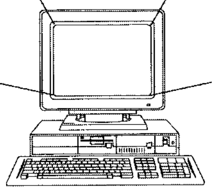
Y=voltage(V)
Ref=Ground X=frequency(Hz)



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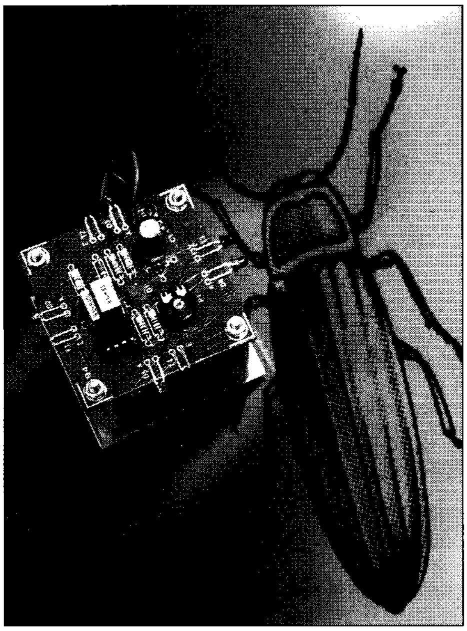
ELECTRONIC FIREFLIES

The circuit described here mimics the behaviour of a firefly, but only if you build more than one. Although it may be a bit bold to speak of group dynamics and conditioned interaction, some very interesting effects can be observed in this cybernetic modelling experiment based on simple electronics. Interested? Then read on.

Design by H. Bonekamp



THE electronic firefly being an example of an artificial animal, it is, strictly speaking, also a cybernetic model with its own, characteristic, behaviour in the presence of members of its species. Since these members communicate via optical means, a group of electronic fireflies really is an opto-cybernetic model in which interactive behaviour may be observed.

Fireflies are beetles emitting phosphorescent light. If you have ever seen the beautiful light patterns produced by a swarm of fireflies, the effect is not unlike synchronous oscillation. In some people, the effect induces deep thoughts, while others are hypnotized, or, in any case, touched by such a wonder of nature.

From biology to electronics

To be able to mimic positive phototactic behaviour of a firefly you first of all need a small, oscillator-controlled, flashing light which is clearly visible in the dark. Furthermore, some means has to be provided to control the flash rate (in other words, the oscillator frequency), and an optical output signal to be able to control a second oscillator.

The circuit diagram in **Fig. 1** shows that the above requirements are easily realized with practical electronics. The heart of the circuit is the familiar and inexpensive 555 timer. The optical sensors and emitters of the model are realized by a set of infrared LEDs and phototransistors.

The 555 is wired as an astable multivibrator. The principle is both simple and effective. In the configuration used here, the 555 acts like a switch which closes when the d.c. voltage at the threshold input (pin 6) rises above two-thirds of the supply voltage, and opens again when it drops below one-third of the supply voltage. The threshold input is connected to a capacitor, C_2, which is charged via P_1-R_1-R_4 as long as the 'switch' formed by the 555 is open. Any time the capacitor voltage rises above the above mentioned threshold level, the capacitor is discharged via pin 7 of the 555, and the Q output (pin 3) drops low. This is used to switch on a LED, D_1. Since the charging and discharging of C_2 is repeated continuously, LED D_1 flashes at a certain rhythm, and so forms the 'light' of the firefly. The flash rate is determined by P_1, R_1 and C_2, and works out at about 1 Hz. The ratio $(P_1+R_1)/R_4$ determines the mark/space ratio, (duty factor) of the LED control signal.

So far, the circuit looks like an ordinary flashing LED. The specialty, however, is the addition of T_1-T_4 and D_2-D_5. The latter are infrared emitting diodes (IREDs) which produce the optical transmitting signal of the firefly. The series-connected IREDs are simply connected in parallel with D_1, and emit infrared pulses in the same rhythm as the ordinary, visible light LED. The aim is, of course, that the IR pulses are picked up by another firefly, via transistor T_1, T_2, T_3 or T_4. When these phototransistors detect infrared light, they start to conduct, causing the voltage across R_5 to drop. This voltage is used to assist in the charging of C_2, via diode D_6, causing the capacitor to be charged a little faster than normal. The result is a brief phase shift of the flashing signal, causing the next flash to occur a little later than normal.

Since the voltage across C_2 never drops below one third of the supply voltage, diode D_6 will not start to conduct until the voltage at the emitter of one of the phototransistors has risen to that level plus the diode's forward drop. The value of R_5 therefore determines the sensitivity of the phototransistors. Because the current through the IREDs is limited by the battery capacity, the distance between the IREDs on one firefly the phototransistors on another should not be more than a few centimetres. As soon as two of these 'creatures' are placed within a small distance of each other, each of them will pick up the infrared light emitted by the other. Provided their flash frequencies are equal, their light pulses will coincide after a while.

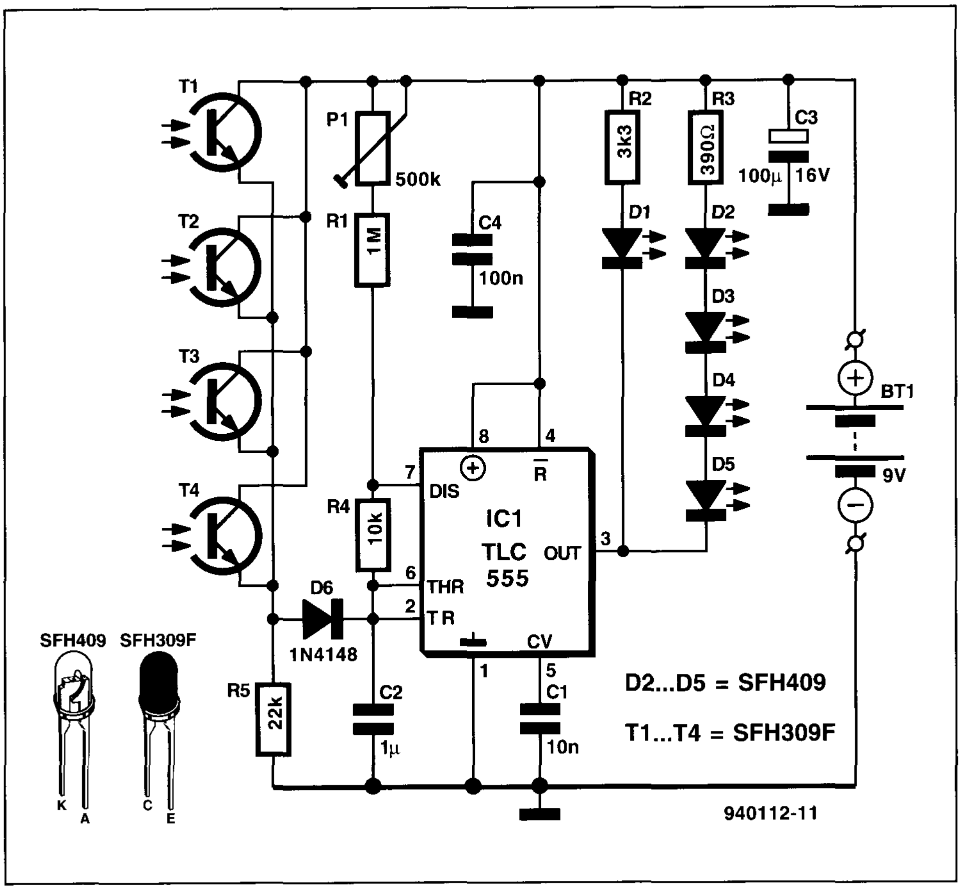
Printed circuit boards

The artwork of the printed circuit board designed for the electronic firefly is shown in **Fig. 2**. Building up should not present problems as there are no special components or construction methods to grapple with. Unfortunately the printed circuit board is not available ready-made trough our Readers Services, so you have to make it yourself.

Since each side of the board has one IRED and one phototransistor, the firefly is capable of looking for other members of its species in four directions. Obviously, it makes no sense to build one firefly only. The fun starts at four or so of these little beasts.

All fireflies have to be adjusted for the same flash frequency. Fortunately, that can be achieved without special test instruments. However, to prevent the behaviour of the circuit being influenced, the adjustment should be made at the lowest possible ambient light intensity. The following order is recommended.

1. On one of the fireflies, turn preset P_1 to the centre of its travel, and use this board as the reference.
2. Count the number of flashes in one minute.



COMPONENTS LIST

Resistors:
R_1 = 1MΩ
R_2 = 3kΩ3
R_3 = 390Ω
R_4 = 10kΩ
R_5 = 22kΩ
P_1 = 500kΩ preset H

Capacitors:
C_1 = 10nF
C_2 = 1µF MKT
C_3 = 100µF 16V radial
C_4 = 100nF

Semiconductors:
D_1 = LED (green) low current
D_2-D_5 = SFH409 (Siemens)
D_6 = 1N4148
T_1-T_4 = SFH309F (Siemens)
IC_1 = TLC555

Miscellaneous:
9-V PP3 battery + clip.
PCB not available ready-made through the Readers Services.

Fig. 1. Circuit diagram of the electronic firefly. This little beast has optical senses.

3. Put the reference board away ('out of sight' of the others), and fetch the second board.
4. On this board also, set P_1 to the centre of its travel. Next, count the number of flashes in one minute.
5. If the number of flashes is greater than that produced by the reference board, turn P_1 anti-clockwise. If the number of flashes is smaller, turn P_1 clockwise.
6. Count the number of flashes per minute again, and adjust P_1 until the frequency is less than or equal to two pulses with respect to the reference. This adjustment is sufficiently accurate for the present purpose.

The other boards are adjusted in the same way. Although this may seem tedious and time-consuming, in practice the correct setting of P_1 is rapidly found.

Next, you can start thinking about a practical and attractive enclosure for the fireflies. Almost anything may be used, provided the view of the photo-

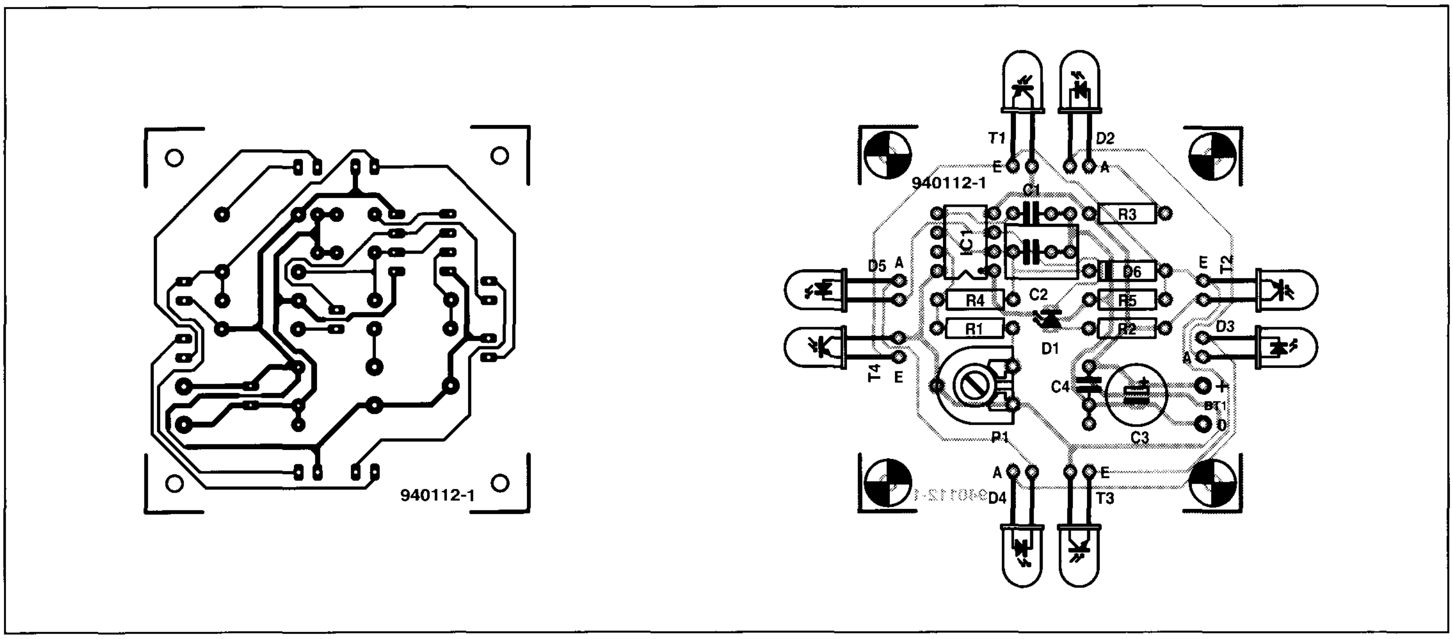


Fig. 2. The PCB design allows the firefly to communicate with other members of its species via all four sides of the board.

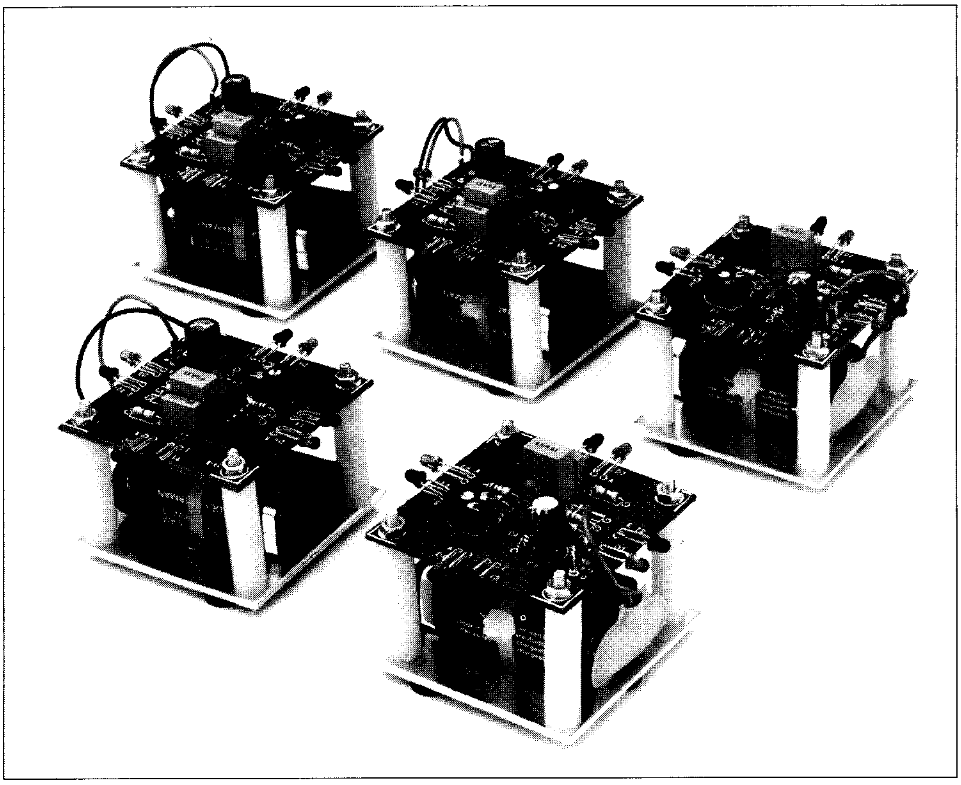


Fig. 3. The fun starts when you build a number of fireflies.

FIREFLIES

A firefly is not a fly, but a kind of beetle which is so named because of its ability to emit phosphorescent light. Both males and females have a unique light emitting organ at the rear end of their body. This organ consists of different layers of which the inner one functions as a reflector. The actual production of visible light is caused by a chemical reaction of two substances which are made by the insects themselves. The reaction is started by stimuli from the nervous system.

In general, it is assumed that the light serves to attract members of the opposite sex. The females (who can not fly) usually attach themselves to the top of grass blades, and turn the rear end of their body towards males flying over them. They respond to light signals emitted by an attractive male by boosting their own light intensity. To be able to detect these signals emitted by the females, the males have large hemispheric shaped eyes.

transistors and IREDs is not blocked. As illustrated by the introductory photograph, the prototypes were not mounted in cases at all. Each board was fitted on an aluminium base plate with the aid of four PCB spacers. The base plate serves to hold the 9-V battery, which is held in place by a plastic cable tie. This leaves the fireflies entirely mobile.

Experiments

When all boards are adjusted as described earlier, it is time to do some experimenting to see if synchronous light effects actually occur. A good impression of the typical behaviour of the circuit, and the optimum distance, is obtained by starting with two fireflies. Although it is not necessary to do the experiment in absolute darkness, ambient light should be kept to a minimum.

Switch on two fireflies, and place them at a distance of about 10 cm. In the rare case of the two already flashing in unison, keep them out of each other's sight for a couple of minutes, and then slowly move them towards each other, ensuring that the optical parts on the boards can see each other. Carefully watch the flashing of the two fireflies. At a certain instant, you will note a steady synchronization between the two flashers.

After moving the fireflies around on the table for a while, it will be noticed that the distance for the quickest synchronization is about three centimetres. When the distance is smaller, the LEDs will remain on all the time.

Next, put a third firefly on the tabletop. Notice that the synchronization of the first two may be disrupted by the third if it is slowly moved into their sight. Here, too, the flashing changes to steady 'on' if the distance between the fireflies becomes too small.

Introducing a fourth member into the group allows a square configuration to be made, which causes a loop in which a kind of positive feedback effect occurs. Here, the distance between the fireflies becomes even more critical than with three members.

In the 'square' arrangement, it is best to start with a distance of about 4 cm between the boards. Next, move them closer a millimetre at a time. If the LEDs light continuously after a while, the distance has to be increased again. If the LEDs do not start to flash again, the 'lock up' situation can be cancelled by inserting a piece of cardboard between two fireflies, which interrupts their optical link. If the lock-up effect occurs again after a while, the distance has to be increased a little again, and the trick with the cardboard is repeated. With a little patience, quite interesting synchronization patterns may be obtained with four fireflies. During some experiments with prototypes, it appeared that heat (IR) radiation emanating from persons close by the fireflies sometimes had an effect on a synchronization pattern.

Finally

To complete the story, a few figures. The flash rate is set to about 1 Hz. The current consumption of the circuit is about 14 mA, of which 2 mA goes to D_1, and 10 mA to the four IREDs.

If you want to increase the range of these creatures, consider increasing the current through the IREDs. This is best done by lowering the value of R_3. Note, however, that the minimum value is about 56 Ω. At this value, the IREDs pass a current of about 100 mA, which will considerably shorten the battery life.

(940112)

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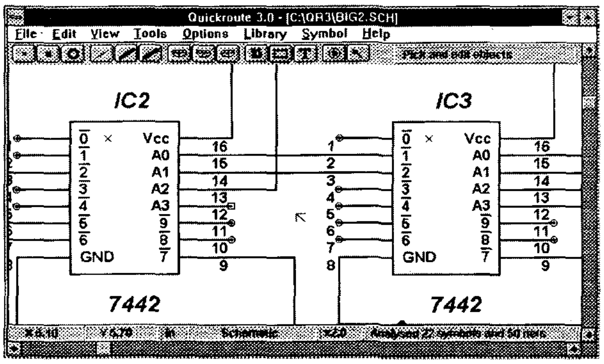
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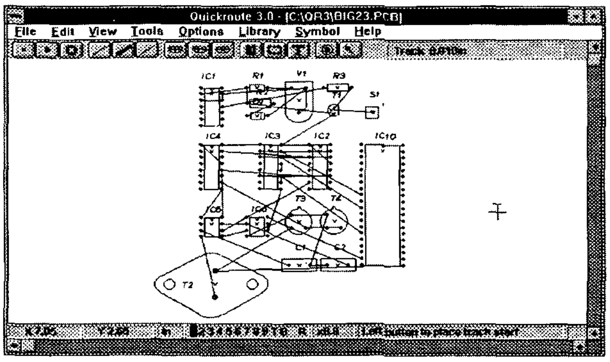
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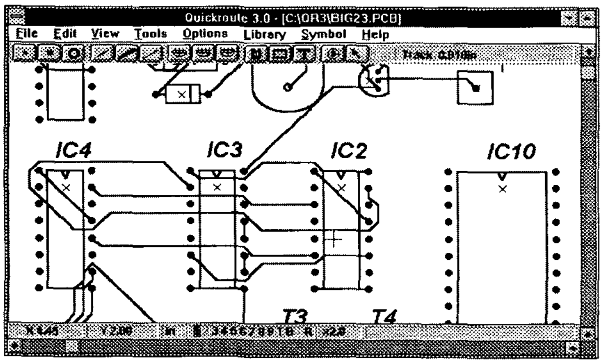
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MOCK CAR ALARM

Although it has no detector or alarm actuation device of any kind, the present circuit may still function as a deterrent against car thieves. Actually, a vigilantly flashing LED in your car simulates an armed car alarm which is not there at all.

Design by L. Lemmens

IN this day and age any car owner should be painfully aware that his or her trusted vehicle can be broken into or stolen at almost any time and place. Car burglary and car theft is such a massive problem that it seems to grow beyond the capacity of the police. Not surprisingly, certain cars have to be fitted with an approved alarm system before they can be insured at all. In the car shops, too, shelves are loaded with anti-theft radios, wheel locks, gear lever locks and a wide range of electronic car alarms.

Most locks and clamps are brightly coloured, while the alarm systems usually come with a flashing LED, and a set of bright stickers for fitting on the car windows, warning potential thieves that the car is fitted with an alarm. However, since there is no way of telling whether or not an alarm is actually fitted or not, it is also possible to mount just a flashing LED, which hopefully acts as a deterrent.

A comparator

In principle, such a mock car alarm consists of only two parts: a flashing LED and a series resistor of about 150 Ω. Most of you will know perfectly well how to connect and install such a mock indicator. The disadvantage of this super-simple solution is that the LED will flash all the time, and that can be dangerous while you drive the car because it has a distracting effect. Obviously, it is possible to add a switch to turn the LED on and off, but that is cumbersome. Ideally, the LED should be on only when the car is parked, and off when it is driven. How that can be achieved without tampering with the car's electrical wiring system is discussed below.

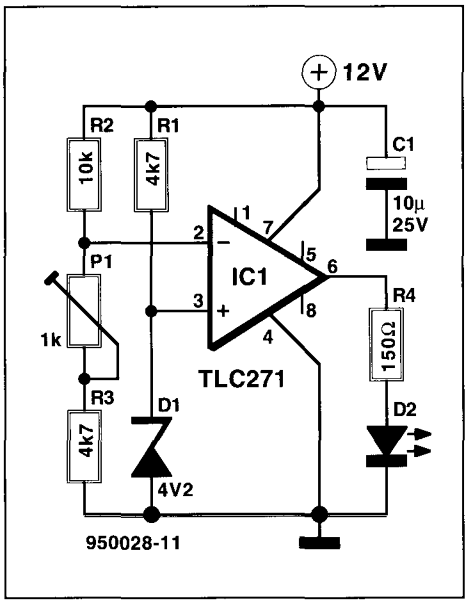
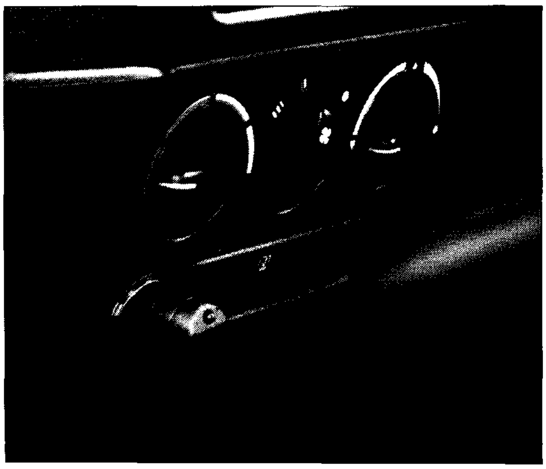


Fig. 1. Circuit diagram of the mock car alarm. No need to switch the flashing LED on and off any time you enter or leave the car, that is done automatically for you by a comparator which monitors the car battery voltage.



The switching on and off of the flashing LED is controlled by an accurate comparator which measures the car battery voltage. When the engine is running, this voltage will be of the order of 14 V. When the engine is switched off, the battery voltage drops to a value between 12 V and 12.5 V. With the comparator's threshold level set to a value just under 13 V, the LED is switched off automatically when the engine is started, and on, when the engine is switched off.

With reference to the circuit diagram in **Fig. 1**, opamp IC_1 is wired as a comparator which compares the two voltages applied to its inputs. The comparator output is high (and the LED is switched on) when the voltage at the +input is higher than that at the –input. The voltage at the +input is fixed at +4.2 V with the aid of zener diode D_1 and resistor R_1. These parts make the reference level is independent of the car battery voltage. The –input of IC_1 is tied to the junction of an adjustable voltage divider. The voltage at this junction varies along with the battery voltage, and may be set to a value between 3.8 V and 4.4 V when the battery voltage is 12 V, and between 4.5 V and 5.1 V when it is about 14 V.

Preset P_1 is used to adjust the voltage at the –input to a level just under the reference of 4.2 V, when the engine is switched off. The LED then starts to flash, but it will go out the instant the engine runs, because then the –input of the comparator rises above the threshold of 4.2 V, and the comparator output drops from high to low.

Construction

A printed circuit board is really not needed for such a simple project with so few parts. The circuit is easily built on a piece of veroboard or stripboard, or, even simpler, as a 'flying wire' construction. The latter option may be the smartest because it allows the shape to be matched to the enclosure used. For this, a plug for the cigarette lighter socket in the dashboard is suitable. The flashing LED then protrudes from the cable opening in the plug. Although the plug is a convenient and low-cost solution, it is rather conspicuous as a mock alarm, and will almost certainly fail to deter experienced car thieves. If you want to make the warning device look as authentic as possible, it may be better to fit it in a small box, or in the dashboard.

Finally, **Fig. 2** shows a prototype, while the other photograph on this page illustrates how the project may be finished neatly. (950028)

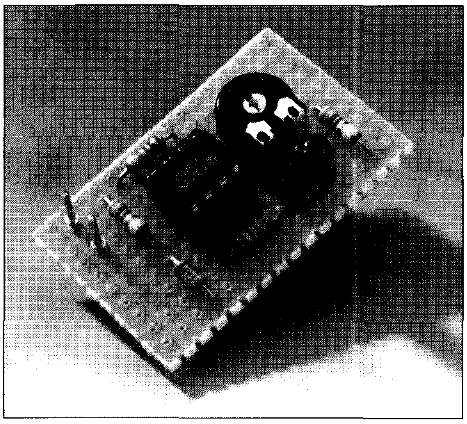


Fig. 2. A simple circuit like this is easily built on a small piece of stripboard.

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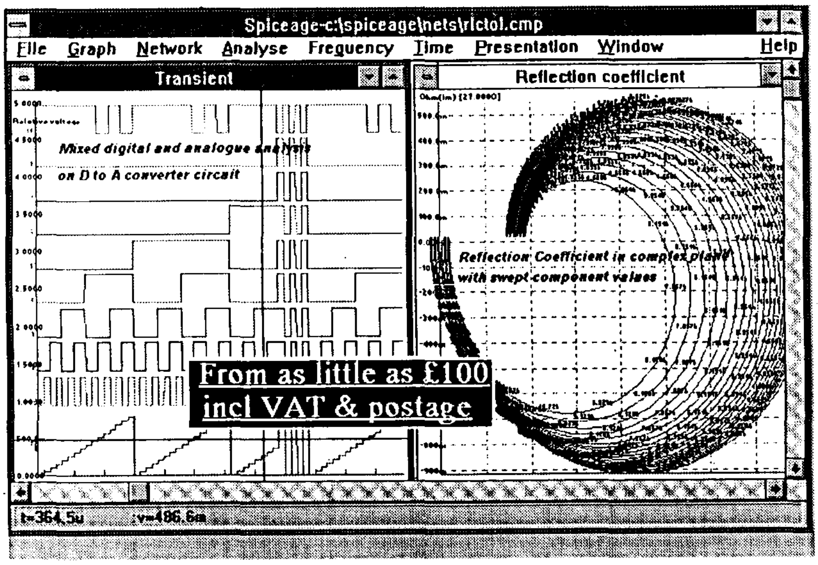
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Electronic Circuit Design Ideas

By V. Lakshminarayanan
ISBN 0 7506 2047 1
Price £ 19·95 (soft cover)

In 14 chapters, using over 170 circuits, this compendium contains a wide range of interesting and illustrative circuit design ideas. Each idea consists of a circuit diagram, waveforms (where applicable), and a simple explanation of how each circuit works. In many cases, relevant design equations and formulas are also shown, so that the full lesson offered by each can be appreciated.

Not only will this collection be useful for students at all levels, it also provides a valuable ready reference for design engineers, consisting as it does of many circuits that are the building blocks of larger system designs. Each component is fully described, and data sheets are provided where appropriate. These are ingenious designs which are accompanied by all necessary information to get them to work.
Published by Butterworth-Heinemann*.

Logic Design

By Mike Wharton
ISBN 0 7506 2122 2
Price £ 9·95 (soft cover)

This book, based on a series of feature articles from *Electronics, the Maplin Magazine*, offers a clear introduction to logic circuit design. As well as providing a first guide for the beginner, the book includes practical information and reference material for the more experienced electronics amateur or student. It will doubtless be found useful to constructors, students and experimenters.

The contents include: Power to the people; chips and gates; solution to problems; hexadecimal numbers; building a timer/counter; more chips; CMOS devices; crystals; multiplexing; microprocessor-based systems.
Published by Butterworth-Heinemann*.

*Butterworth-Heinemann books can be ordered from Reed Book Services, PO Box 5, Rushden, England NN10 9YX.

CeBIT95

From 8 to 15 March the annual CeBIT Fair (formerly Hannover Fair) takes place in Hannover, Germany. Over the years, this fair has become a byword for size and excellence all over the world. As in past years, visitors will find in and on the stands of some 6000 exhibitors from 57 countries much that is new and exciting. This year, much attention is being paid to the latest developments in communications, both wireless and via networks such as ISDN*. Apart from digital systems and new hardware, a number of exhibitors will show the integration of ISDN into industrial and commercial networks. Examples are support of standard public telephone services like automatic call division and the coupling with monitors in the workplace to enable fast access to customer data.

Many exhibits are clearly aimed at the many potential customers in industrial and commercial enterprises who now use data communications. Many of these want to change over from the X.25 links to the more-embracing and less expensive ISDN network.

There are also exhibits of computer-to-computer communication via ISDN broadband networks and new ISDN cards for PCs.

For the first time, coupling elements and converters for planned public and private ATM (Asynchronous Transfer Mode) networks will be shown. This protocol will make the digital highway accessible to the consumer.

Other exhibits include interfaces that enable fax machines to be used as scanners and printers for PCs.

Many network operators, distributors and service agents will demonstrate regional, national and international cable communication services.

Much attention will also be paid to the (wireless) GSM (Global System Mobile) cellular telephone systems. These systems, which operate in the 900 MHz band, can now also be used for non-voice applications, such as fax and data communication. Exhibitors will also pay attention to PCN (Personal Communication Network) services. Furthermore, many stands will have information on the DECT (Digital European Cordless Telephone) standard.

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* Integrated Services Digital Network.

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Components for projects appearing in *Elektor Electronics* are usually available from appropriate advertisers in this magazine. If difficulties in the supply of components are envisaged, a source will normally be advised in the article. It should be noted that the source(s) given is (are) not exclusive — other suppliers may also be able to help.

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In resistor and capacitor values, decimal points and large numbers of zeros are avoided wherever possible. Small and large values are usually abbreviated as follows:

p (pico-) = 10^{-12}
n (nano-) = 10^{-9}
μ (micro-) = 10^{-6}
m (milli-) = 10^{-3}
k (kilo-) = 10^{3}
M (mega-) = 10^{6}
G (giga-) = 10^{9}

Examples:
1kΩ5 = 1.5 kΩ = 1,500 Ω
2μF2 = 2.2 μF
6V3 = 6.3 V
Note that nano-farad (nF) is the international way of writing 1000 pF or 0.001 μF.

Resistors are 0.5 watt, 5% metal film types unless otherwise specified.

The direct working voltage of capacitors (other than electrolytic or tantalum types) is assumed to be ≥60 V. As a rule of thumb, a safe value is about 2x direct supply voltage.

Direct test voltages are measured with a 20 kΩ/V meter unless otherwise specified.

Mains (power line) voltages are not normally listed in the articles. It is assumed that our readers know what voltage is standard in their part of the world.

Readers in countries that use 60 Hz supplies, should note that our circuits are usually designed for 50 Hz. This will not normally cause problems, although if the mains frequency is used for synchronization, some modification may be required.

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The size of a metric bolt or screw is defined by the letter M followed by a number corresponding to the overall diameter of the thread in mm, the x sign and the length of the bolt or screw, also in mm. For instance, an M4x6 bolt has a thread diameter of 4 mm and a length of 6 mm. The overall diameter of the thread in the BA sizes is: 0 BA = 6.12 mm; 2 BA = 4.78 mm; 4 BA = 3.68 mm; 6 BA = 2.85 mm; 8 BA = 2.25 mm.

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March 1995

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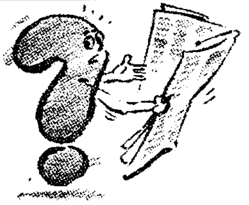

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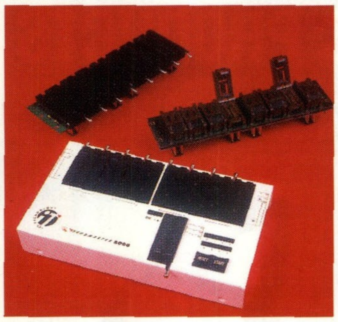

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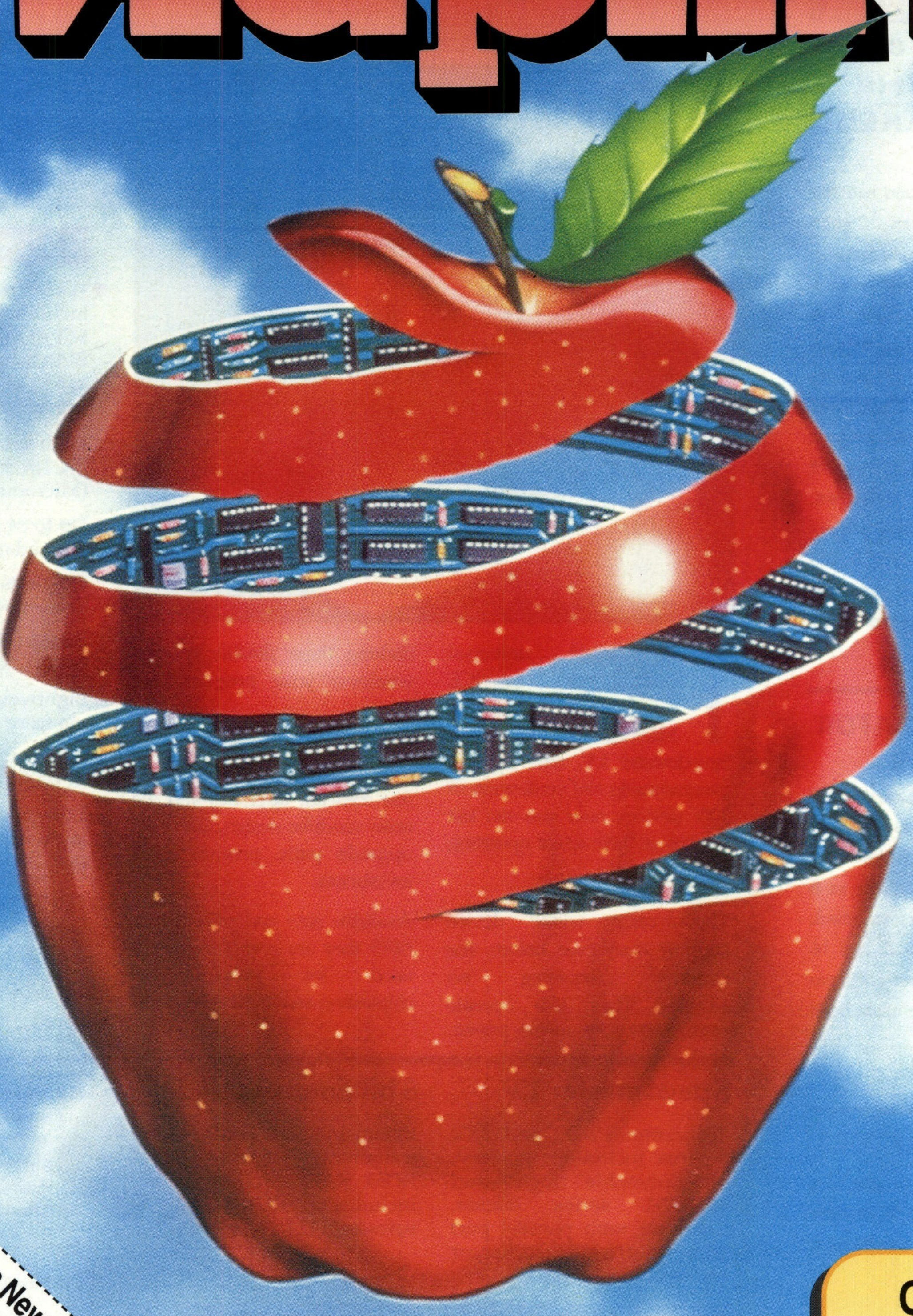

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